



ILLINOIS STATE GEOLOGICAL SURVEY ANNUAL REPORT

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Illinois Department of Energy and Natural Resources
STATE GEOLOGICAL SURVEY DIVISION

**ANNUAL REPORT
TO THE
BOARD OF NATURAL RESOURCES
AND CONSERVATION**

June 1991 to July 1992

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ISGS HIGHLIGHTS AND SUMMARY, 1991-1992

During the past year, the Illinois State Geological Survey (ISGS) along with the Natural History Survey the State Water Survey, and the Hazardous Waste Research and Information Center endured major disruptions, including the threat of restructuring and reorganization within state government and the reality of severe budget cuts. Yet the ISGS continued to serve the public, private, and government sectors—not only as a research and service institution providing credible, unbiased science, but as a source of information on the state's natural resources. As a result of its unfailing efforts to promote sound economic development and environmental protection in Illinois, the ISGS presents a proud record of accomplishments for 1991-1992.

Programs in coal, oil and gas, industrial minerals, and groundwater resources contributed directly to the state's economy. Resources for today and tomorrow were identified and estimated in several investigations of fuels and other mineral resources. The ISGS generated information, ideas, and incentives along with new technologies through its programs to help promote investment and create jobs in Illinois. Several technologies to encourage greater utilization of Illinois coal were introduced; for example, the ISGS proprietary method for producing a supersorbent, high-surface-area, hydrated lime for removing SO₂ during coal combustion was readied for pilot plant scale-up. The ISGS program for improving oil recovery from existing reservoirs through reservoir characterization and better reservoir management received national recognition. Another program stimulated queries, interest, and development activities as the results of a 6-year study on the undiscovered mineral potential of southern Illinois were released to industry. Also, the potential for new water supplies was identified for a number of rapidly expanding communities in Illinois.

A benefit/cost study highlighting the value of geologic mapping to help waste disposal facilities avoid clean-up costs was published (ISGS Circular 549). Benefits of geologic mapping in Boone and Winnebago Counties were estimated to outweigh costs by up to 27 times. Other efforts to protect the environment included technical assistance to counties to help site landfills, development of procedures to measure and monitor pesticide movement in groundwater, and assistance to the Illinois Department of Transportation in identifying conditions related to highway construction near wetlands so that these areas can be properly maintained, restored, or replaced. Inroads were made in identifying chemicals that could adsorb and inhibit the movement of pesticides in the subsurface and into the state's groundwater supplies.

Information on earth hazards resulting from ongoing investigations was used to help protect the Chicago shoreline from erosion, locate sand supplies for beach replenishment, and provide guidance to those dealing with mine subsidence.

Especially newsworthy was ISGS assistance to industry and to the U.S. Corps of Engineers this past spring, when data were needed on the nature of earth

materials surrounding the flooded freight tunnels under downtown Chicago. Information on the nature of the clay materials supported the idea that the tunnels could be rapidly dewatered without affecting building foundations. The disaster would have been even more costly if the tunnels had to be slowly dewatered. This is but one example of the use of the vast ISGS databases. It demonstrates that the ISGS can respond to emergencies quickly and effectively, as a consequence of maintaining a database on earth resources and a trained cadre of scientists and engineers.

If ever there was a time for geological programs in support of economic development and environmental protection, now is that time. Yet budget cuts as serious as any cuts ever suffered by the ISGS resulted at year's end and seriously affected the FY93 budget. By contrast, during the Great Depression of the 1930s, support for the State Geological Survey remained strong and even led to increases. ISGS research and mapping were viewed as investments in the economic development of the State. That mission is valid today, with the added commitment to protect the environment.

The wisdom of the 1930s led to major successes in coal research, significant increases in oil production from the Illinois Basin, and more jobs in all sectors of the State's economy. That wisdom is needed again in the 1990s, as Illinois struggles to right itself from the effects of a persistent and pervasive recession.

MINERAL RESOURCES AND ENGINEERING

The total value of mineral production in 1991 declined from \$2.6 billion to \$2.4 billion. Decreases in value were recorded for coal, oil and gas, and industrial minerals, as a consequence of the recession and of the recently enacted amendments to the Clean Air Act.

Coal

- The coal mining industry continues in a state of uncertainty. Illinois produced 60.0 million tons of coal in 1991, a slight decrease from the 61.7 million tons produced in 1990.
- The 1991 update of Illinois Coal Mine Maps was completed and new maps produced for 23 counties. There are 80 maps and directories for 73 counties in this 1:100,000-scale map series.
- The Coal Section's database was considerably enhanced with the donation of more than 20,000 drill hole records from the Midland Coal Company.
- In the first of several studies of quadrangles, an evaluation of the availability of coal resources for development indicates that less than 60% of the resources are available for mining and possibly less than 25% may actually be recoverable.

• Factors limiting availability of coal in the Middletown Quadrangle include weak roof and floor rock, thin bedrock cover, unfavorable stripping ratios, thin coal, and surface features such as cemeteries and interstate highways.

A



B



D



(A) Geologists E. Donald McKay and Robert J. Krumm discuss a three-dimensional model of Lake County. (B) Donald F. Oltz, head of Oil and Gas Section, speaks to a group of oil operators and petroleum geologists and engineers at a joint meeting of the petroleum and technical advisory committees for the Improved Oil Recovery project. (C) Joseph A. Devera, field geologist and paleontologist, and Heinz H. Damberger, head of the Coal Section, discuss results of the COGEOMAP program at a meeting of the Illinois Geologic Mapping Advisory Committee. (D) Geologist Robert A. Vaiden and his daughter, Jackie, look for fossils and minerals during the Galena geological science field trip.

C



- Experiments indicate that chlorine in coal sample IBC-109 is released solely as HCl gas, not as NaCl, during pyrolysis and gas combustion. The HCl release profiles show a broad peak between 250°C and 600°C with a maximum at 445°C. In contrast, the sulfur release profiles show three peaks: one around 370°C, perhaps derived from elemental sulfur; another at 475°C, corresponding to the main component of organic sulfur; and the third at 600°C, corresponding to the decomposition of inorganic pyritic sulfur.

- Results from a synchrotron XRF microprobe facility indicate that a suite of cleat calcites from the Herrin and Springfield Coals were not precipitated from seawater, but from meteoric fluids in joints in the coal seams.

- For coal IBC-101, a straight line relationship has been found between ash content and each of the organic properties: Btu, organic sulfur, volatile matter, fixed carbon, hydrogen, and nitrogen.

- Analysis of surface properties of eight fresh and oxidized coal bank samples indicate that significant variations exist in the surface area and pore size distribution of the coals. These observed differences may be useful in predicting differences in the physical-chemical behavior of these coals during coal cleaning, conversion, and combustion.

- Experimental results indicate that carbonation, or reaction of carbon dioxide with calcium hydroxide to produce a binding matrix of calcium carbonate in coal pellets, improves their quality and serves to "weather-proof" the pellets. Sulfur captures of greater than 70% have been achieved for some samples in laboratory tests at 850°C, a temperature in the range of operation for fluidized-bed combustors. This research could improve the marketability of approximately 5% of the State's annual coal production that is currently discarded because mechanized mining procedures leave it too fine to be acceptably transported.

- A flotation column, 30 inches in diameter by 35 feet in height, was contributed by Deister Concentrator Company for a cooperative study by the ISGS with the Kerr McGee Coal Corporation and Deister. The column provided an improved concentrate with respect to grade of product, recovery of energy units, and less power consumption over the conventional, froth flotation process now used in the Kerr-McGee plant at Galatia, Illinois.

- Arthur Conn and Associated Ltd. completed an economic study indicating the costs of sulfur removal (\$ per ton of SO₂) in dry sorbent systems is about \$150 to \$200 for the ISGS high-surface-area hydrated lime (HSAHL) versus \$250 to \$300 for a commercial hydrate (sorbent and disposal costs only). Another study by the ISGS revealed that utilities could save between \$0.5 to \$6 million per year (depending on plant size, which ranged from 100 to 500 MW) by using HSAHL instead of commercially available hydrated lime.

- Plans to construct a scaled-up 1-ton-per-hour pilot plant are underway with ISGS industrial partners, Dravo Lime Company and Kennedy Van Saun (KVS). The ISGS assisted Dravo and KVS to design the facility to produce 600 tons of HSAHL for testing at Illinois

utilities. To date, the Illinois Coal Development Board, Dravo, and KVS have committed \$2.5 million toward the construction of a \$3.2 million pilot plant.

- Chars prepared from IBC-102 coal in a fixed-bed reactor have been produced with commercially significant surface areas of 1500-2100 m²/g, when potassium hydroxide was used as a chemical activant. These high-surface-area chars have more than twice the adsorption capacity of commercial carbon and zeolite molecular sieves.

- A 20% ultraclean coal to 80% diesel fuel slurry was tested in a modified two-cylinder diesel engine at the University of Illinois at Urbana-Champaign (UI-UC). Tests indicate that the low-ash coal can be successfully substituted for diesel fuel in the slurry.

- The Illinois Basin Coal Sample Program now contains 11 lots of coal from which samples may be delivered to researchers around the world. Eight were collected from Illinois; three are from Indiana mines. The availability of well characterized, Illinois Basin coals has leveraged a modest Illinois investment into worldwide research on Illinois coals funded by other governments and private industry.

- The Coal Analysis Laboratory analyzed 840 samples—a process requiring about 4,000 individual determinations during the past year.

- Among the many requests handled by the Coal Section this past year were about 150 separate inquiries, following a newspaper report on the potential for mine subsidence in an area in St. Clair County.

Oil and Gas

- Annual production of oil in Illinois in 1991 fell to 19,069,000 barrels, 4.4% less than in 1990 and the lowest total in more than 50 years. Also, 1,400 wells were plugged in 1991.

- At the invitation of the U.S. Department of Energy (USDOE), four members of the ISGS Improved and Enhanced Oil Recovery Project team traveled to Washington, DC, in March 1992 to meet with James Randolph, the Assistant Secretary for Fossil Energy. They outlined the project design and summarized results to date. The Illinois program was singled out as one of the USDOE's state/federal programs that clearly met goals and expectations for advanced reservoir characterization and reservoir management.

- Significant progress was made in completing the studies of reservoir heterogeneities and variations in reservoir management of 15 oil fields in southern Illinois. One study has been published and three others submitted for editing. The studies show that an awareness of the complexities of subsurface reservoirs and the need for proper reservoir management can lead to the production of significant quantities of bypassed mobile oil.

- Field work on sandstones of the Mississippian Cypress Formation, exposed in four parallel roadcuts along Interstate 57 in Union County, was completed. The outcrops are analogs for petroleum-producing horizons in the subsurface farther to the north. The details of reservoir heterogeneity documented by the study help in visualizing the heterogeneity of similar

reservoirs at depth. As the data contribute to understanding the complexity of reservoirs, this understanding leads ultimately to strategies for improved oil recovery.

- Interim results from the jointly funded, USDOE/Illinois Improved Oil Recovery studies of 15 fields were showcased at a technology transfer workshop held in Mt. Vernon, Illinois; 145 representatives of the Illinois independent oil industry gathered to hear the results:

Bartelso Field: subdivision of the Cypress Formation in the field for enhanced reservoir management.

Dale Consolidated Field: creation of a stratamodel and reservoir simulation model of two units in the field; recognition of the role of induced fractures in causing poor sweep efficiency; and ideas for improving sweep efficiency with optimal waterflood strategies.

Energy Field: recognition of the effects of reservoir heterogeneity in the Field, which has more than 500,000 barrels of unrecovered mobile oil. The results of a simulation model suggest that strategic location of infill wells, along with properly designed waterflood programs, will enhance recovery from this field.

King Field: creation of a three-dimensional model that characterizes reservoir architecture so that geologists and engineers can design cost-effective ways to recover additional reserves. About 1 to 2 million barrels of mobile, bypassed oil were identified in this field and may yet be produced by conventional means.

Tamaroa Field: recognition of compartmentalization of vertically stacked marine bars and the importance of pressure maintenance in each correlative sandstone unit. Recovery efficiency was found to be highly variable in the different field segments, but also found to be 43% for the more effectively managed reservoirs.

Zeigler Field: identification of the value of pressure maintenance in the field, where recovery efficiencies are 50% or better—far exceeding industry averages.

- 10½ miles of high resolution, seismic reflection data was acquired for the vicinity of King Field in Jefferson County. Preliminary interpretation, integrated with in-field well logs and other data, suggests that stratigraphic variation in the Aux Vases Formation has some response in the seismic data, and in turn, the stratigraphic variation has some control on oil production. Whether high resolution seismic data can be used to help define the field limits warrants further study.

- Regional petrographic study of selected Aux Vases reservoirs: results indicate that modifications during and after deposition of sediments are responsible for development of contrasting reservoir rocks in the Aux Vases over the study area.

- Aux Vases and Cypress sandstones: the mixed layering recognized in chlorites in the clay fractions of these sandstones has led to studies of their impact on fluid flow properties.

- Sailor Springs Field: a database of more than 2,000 electric logs plus selected cores and cuttings have been used to map the distribution of an anastomosing network of thick, distributary, Tar Springs sand bodies in the Sailor Springs Consolidated Field in Clay County. The study showed the lower Tar Springs pay zone comprises relatively thin, shale-bounded, transgressive bar sandstones draped across compaction anticlines. A strong indication of a heretofore unknown linear fault trend was found to align with recently discovered reverse-faulting at Johnsonville Consolidated field about 15 miles to the southwest. Fracturing of the underlying Glen Dean Limestone along this trend could have allowed upward migration of hydrocarbons into Tar Springs reservoirs at Sailor Springs.

- Development of computer-generated maps to replace the older ISGS series of hand-drawn oil and gas development maps continues; 24 computer-generated maps are currently available. Each map covers a 3 by 3 township and range area.

- A QuESToR program has been developed to allow access to ISGS well databases by a "point and click" windowing scheme (x-windows). The program may be used by the general public to view basic well data and determine what other data may be available as paper records in ISGS files. A scheduled commercial release of this program was planned for the International Oracle Users Group Conference in San Francisco.

Other Energy Sources

- A stratigraphic database of the New Albany shale has been created from information on 5,223 wells in the Illinois Basin. The Illinois Basin Consortium, under contract to the Gas Research Institute, is using this database to assess the gas potential of the New Albany shale.

Groundwater

- A study of regional groundwater resources focused on the Prairie Aquigroup in northern Illinois and shallow bedrock aquifers of northwestern Illinois. Another long-term study of the flow system within the Illinois Basin began. Local aquifer studies were completed for five municipalities requesting assistance and initiated for a sixth.

- Responses to service requests in hydrogeology reached a new high in FY92. Telephone responses averaged 120 calls per month; letter responses were up by 70% to 260; and groundwater possibility reports increased by 20% over the FY91 total.

- A study of the Green River Lowland in parts of Whiteside, Lee, Rock Island, Bureau, and Henry Counties led to an updating of studies made in the 1950s. A new well in an area of sparse control showed that a buried bedrock paleovalley is 100 feet shallower than scientists believed when the 1950s map was drawn. The focus of groundwater resources assessment has now shifted from the Green River Lowland area to Boone, Winnebago, and McHenry Counties.

- A study of the Upper Bedrock Aquifer System in northern Illinois resulted in maps showing the elevation of bedrock, thickness of the Silurian bedrock unit,

and thickness of the weathered zone, which has the best potential as an aquifer.

• Clearly defined geochemical regions with three distinct groundwater types have been defined in the Mahomet Valley Aquifer in east-central Illinois. Data suggest that saline groundwater is migrating up from bedrock between Champaign and Piatt Counties and entering the Aquifer.

• A seismic study for the village of North Aurora placed the buried St. Charles bedrock valley about 1 mile farther west than previously thought. Three test wells in the valley were recommended to locate supplies of water.

• In a cooperative study with the Illinois State Water Survey (ISWS), the ISGS completed geologic and hydrogeologic maps and cross sections of Will County and the southern part of Cook County. A computerized base of subsurface data was developed. An updated bedrock topographic map, drift thickness map, and sand and gravel isopach maps were provided to the ISWS as a part of the investigation.

• Electrical resistivity surveys were carried out for ten municipalities, two public supplies, four industries, 18 farms, and 17 private acreages throughout Illinois to assist in locating water resources.

• Borehole geophysical logs were run at 31 sites in the search for water-bearing sand and gravel deposits.

Industrial Minerals and Metals

• During 1980-1990, nonfuel mineral production added \$5.02 billion to Illinois' economy and sustained thousands of jobs in the mining industry.

• Products of the recently completed Paducah CUSMAP (Conterminous U.S. Mineral Assessment Program) were revealed to industry and other interested parties in a joint meeting sponsored by the USGS and the state geological surveys of Illinois, Indiana, Kentucky, and Missouri; the meeting was held in St. Louis in January 1992. Assessments comprised remaining resources of coal, metallic and nonmetallic minerals, sands and gravels, and aggregates in the Paducah Quadrangle, which covers Illinois and adjacent states in an area south of Benton. Well logs, geophysical data, and surface geological information make up the database of sites that have produced commodities including fluorspar (270), tripoli (121), sand and gravel (60), clay and shale (106), and limestone (33).

• The large database created for the CUSMAP project resulted in the development of a number of maps, 52 of which are being distributed through the ISGS Open File Series as printouts from the ISGS electrostatic plotter. Products include bedrock geologic maps, surficial deposit maps, stack unit maps, mineral resource maps, and magnetic and gravity maps of Illinois.

• Three structural cross sections traversing the quadrangle were also constructed. For the first time, a set of regional cross sections for this mineral-rich area is available to the public. Researchers use the cross sections to identify potential oil and gas plays, and to plot the geochemical data that help delineate potential zones of mineral occurrences.

• The map, *Interpretation of Side-Looking Airborne Radar and Satellite Imagery of the Paducah Quadrangle for Lineaments*, was developed. A number of previously unrecognized structures appear on the map.

• Magnetic and gravity studies of the Paducah Quadrangle detailed a prominent continental-scale magnetic lineament that may delineate a northwest-trending shear zone that controlled intrusion in Precambrian time. Interpreted structures and magnetic basement depth suggest that the Reelfoot Graben bends eastward to join with the Rough Creek Graben.

• A high-pass magnetic anomaly map delineates as many as 14 shallow plug-like intrusions in the Paducah Quadrangle. Three of these shallow intrusions coincide with Hicks Dome, Omaha Dome, and Coefield structure. The latter two may have mineral potential similar to that of Hicks Dome.

• Basic geologic and geophysical maps were supplemented by GIS techniques to develop resource assessment models indicating favorable areas for deposits of fluorspar, metalliferous ores, limestone and dolomite, sands and gravels, clay, tripoli, and coal.

• The assessment for coal in the Paducah Quadrangle revealed significant quantities of deep-minable resources with favorable characteristics of thickness and depth, even though most lower sulfur and surface-minable resources have been depleted. The assessment found the remaining resources to be in large, contiguous, relatively flat-lying blocks ideally suited for low-cost mining by modern longwall techniques.

• Oil and gas assessments for the Paducah Quadrangle defined regions where oil and gas plays were most likely to exist. A number of possible oil and gas plays were identified.

• ISGS industrial minerals staff assisted the U.S. Army Corps of Engineers and their consultants to develop plans for reservoir construction at McCook Quarry, as a part of the \$3.6 billion program. Information was also provided to the National Power Company of Oakland, California: eight potential sources of high calcium limestone were identified in northern Illinois for possible use at a coal-fired facility in Madison, Wisconsin.

• Data were compiled on the thickness and depth to Pennsylvanian limestone in 11 counties of south-central Illinois—an area that has few quarries. Deposits that can be profitably worked are needed to offset trucking in materials from Mt. Vernon.

• Potentially valuable kaolin deposits have been located within the Neda Formation of the Maquoketa Group in northwestern Illinois.

• ISGS Circular 550 describing the physical and chemical character of Hicks Dome breccias, related to mineralization, and modes of origin is scheduled for release in September 1992. Strongly mineralized breccia bearing fluorine, lead, zinc, barium, niobium, beryllium, titanium, thorium, and rare earth elements is known to occur at depth at Hicks Dome.

• A strong program of technology transfer in industrial and metallic minerals was undertaken during the past year. In January 1992, a CUSMAP workshop was held in St. Louis for industry. CUSMAP

data and maps were exhibited in May 1992 at the 28th Annual Forum on the Geology of Industrial Minerals held in West Virginia. ISGS staff also participated in a workshop sponsored by seven states, the U.S. Geological Survey, and the U.S. Bureau of Mines in September 1991. Participants discussed various means and methods of ensuring the availability of construction materials to meet future requirements of building and rebuilding the nation's infrastructure.

Mineral Economics

- An analysis of the benefits and costs of geologic mapping—the first-of-its-kind—was published as ISGS Circular 549. This study of Boone and Winnebago Counties showed that the benefits from avoiding the costs of cleaning up contaminated groundwater and/or sites outweighed the costs of geologic mapping by up to 27 times and at least three times for the entire state.

- Statistical correlations for a 20-year period indicate that oil prices may have been mainly influenced by supply-side factors such as the cost of finding new oil deposits. Coal prices were mostly influenced by supply-side factors such as interest rates, mine productivity, and growth of low-cost mining in the western states. The price of coal was not linked to the price of oil.

- An integrated market approach for coal—one that encompasses all cost elements from mining to pollution control and waste disposal—was proposed in a paper for the annual meeting of the Society for Mining, Metallurgy, and Exploration. The paper shows that policy decisions must be based on the "total" cost competitiveness of coal. The common failure to use a comprehensive approach has prevented high-sulfur coals from asserting themselves in the market.

- The economic value of High-Surface-Area Hydrated Lime (HSAHL) was highlighted in a paper showing that, in the short run, use of HSAHL for dry sorbent injection could enable many smaller electric utilities to comply with the mandates of the 1990 Clean Air Act amendments.

- The value of industrial minerals was the key point of another paper. Although constituting less than 5% of the U.S. Gross Domestic Product, industrial minerals make the remaining 95% of economic activity possible. As the basis of the nation's infrastructure as well as the housing and industrial sectors, industrial minerals claim high priority in the nation's policies.

ENVIRONMENTAL GEOLOGY AND GEOCHEMISTRY

Environmental Studies and Assessment

- The Critical Trends Assessment Project is a new, cooperative endeavor involving all Divisions of the Illinois Department of Energy and Natural Resources. The recently completed Phase I met its two major goals: (1) definition of elements necessary to conduct a critical trends assessment of the state's environment, and (2) a comprehensive work plan. Among the products delivered was a partially annotated bibliography containing 1,062 entries covering 23 topical areas.

- Two more products were added to the growing library of publications resulting from value-added efforts of using data collected several years ago from the Superconducting Super Collider (SSC). Included were the report, *Illinois Geographic Information System: Applications to Environmental Management*, and the map, *Slope Percent Map of Kane County*.

- During the past year, 100 reports on Illinois Department of Transportation (IDOT) property assessments, representing 275 miles of state highway projects, were completed. The reports include information on historical land use and on the presence of hazards, both man-made and natural. Prime sources of environmental hazards are previously unknown leaking underground storage tanks.

- A database consisting of digitized maps and other data for more than 200 mine permits has been completed for the Illinois Department of Mines and Minerals. During the past year, progress was made on the entry of information on acreage affected by mining and areas for which companies post a bond to ensure appropriate reclamation.

Geology for Planning Studies

- For resource-based, land use planning in Kane County, well log data from an eight-township area were analyzed to produce a three-dimensional model of earth materials above bedrock. The model, when combined with maps, will assist Kane County planners in their siting decisions on public works projects.

Lake Michigan Coast and Basin Studies

- For a monitoring study of the North Point Marina and environs, all digital map data obtained from 1988 to early 1992 were prepared for a CD-ROM to be created by the U.S. Geological Survey. The data include maps showing the annual bathymetry, lake-bottom change, and shoreline change.

- Coastal monitoring at Lake Forest Park Beach by the ISGS on behalf of IDOT revealed (1) a previously unknown accumulation of fine sands in the northern beach area, and 2) a mechanism for littoral sediment bypass around the engineered structures.

- During a 2-year study sponsored by the Illinois Department of Conservation, bottom materials were sampled and mapped in all of Chicago's small boat harbors and in the vicinity of north Lincoln Park and the Edgewater District. Maps were prepared to show the extent of lacustrine sediments and glacial till. Bathymetric data were contoured in 1-foot intervals.

- The project on the distribution and fate of PCBs in Waukegan Harbor sediments sponsored by the Hazardous Waste Research and Information Center has been completed. Research to determine the long term fate of PCB mixtures in aqueous sediments in the harbor continues.

Wetlands, Rivers, and Interior Lakes

- Sedimentation rates were determined at 11 locations along the West Branch of the Lake Calumet River. Whereas most of the river showed low sedimentation rates (<0.1 cm/y), one confined region showed

high rates (>1cm/y). Very high levels of copper, zinc, cadmium, tin, and lead were found. Sediments with high metal content were generally confined to downstream locations near Hammond, Indiana.

- Monitoring of wetlands and characterizing geologic processes continued in the Cache River wetland of southern Illinois; at Volo Bog, the Des Plaines River wetland demonstration project; and a pristine fen in northern Illinois. Three wetland projects were also underway for IDOT, including one at the Black Partridge Forest Preserve, one near the Schaumburg Commuter Rail Station, and one along the Elgin-O'Hare Expressway Corridor.

- The study of a spring-fed wetland in the Black Partridge Forest Preserve indicated that discharge at the spring may be reduced by 8% to 24%, depending on the highway alignment and drainage.

- At the Schaumburg wetland location, baseline conditions were established in 1981 before a commuter rail station, parking lot, and access road were constructed. Sediment and water samples collected in 1992 indicated increasing concentrations of sodium and chloride, probably due to runoff from the adjacent parking lot. Sedimentation rates do not, however, appear to have increased.

Groundwater Protection

- For a groundwater protection mapping project in McHenry County, the ISGS is working with the ISWS to define and characterize aquifers. Two cross sections per quadrangle were completed for about 45% of the quadrangles. Water well locations were verified for about 90% of the quadrangles. A surficial geologic map is undergoing revision.

- Working with Illinois Environmental Protection Agency and the ISWS to conduct a pilot assessment of groundwater protection needs, the ISGS digitized four cross sections, an isopach map for each of four drift aquifers, and a stack-unit map of the Woodstock 7.5-Minute Quadrangle. A method will be developed for incorporating these data into an easily retrievable database.

- A regional model developed in cooperation with the USGS identifies aquifers and ranks sequences of geologic materials by relative potential for transmitting water and contamination from land surface.

- A pilot study was recently completed by the ISGS and ISWS on an experimental design for detecting and monitoring agricultural chemicals in rural, private water wells. A report (published as ISGS/ISWS Cooperative Groundwater Report 14) notes that one or more agricultural chemicals were detected in 23% of the samples analyzed from 240 rural private wells. Nitrate was detected in 42 of the 240 wells sampled; pesticides were detected in 24 of the wells sampled. The results indicate that agricultural chemicals leach into groundwater; however, their occurrence is not uniform over the five study areas. Occurrence is generally controlled by well type (drilled or driven versus dug or bored) and depth to uppermost aquifer.

- The ISGS is assisting the Illinois Department of Agriculture (IDOA) in responding to the 1990 amend-

ments to the Illinois Pesticide Act, which requires IDOA to develop recommendations to remediate pesticide-contaminated soils at the 1,300 agrichemical facilities in Illinois. Assessments were completed for 17 of 19 sites; the analytical data on samples are currently being summarized. Preliminary results indicate that the frequency of contamination detected does not seem to correlate with the age or size of the site. Pesticides have been most frequently detected in gravel layers at the surface of each site.

- In a study on the fate and movement of the pesticide atrazine, the ISGS is investigating the pathway(s) by which atrazine enters the Embarras River. Results indicate that the primary route of atrazine in the study area is by overland flow from the field into a tile drainage system, which in turn discharges into the river. There is little evidence that the atrazine infiltrating into the soil reaches the river.

- In support of the IDOA Pesticide Management Plan, the ISGS prepared a state map (1:500,000 scale) and individual county maps (1:250,000 scale) that identify regions with aquifers vulnerable to contamination by agricultural chemicals. In about 40% of rural Illinois, aquifers lie within 50 feet of the ground surface. In about 60% of rural Illinois, the aquifers are more than 50 feet deep and apparently protected from pesticide contamination by the attenuation capacity of soils and thick sequences of fine-grained materials. Pesticide use, largely for corn and soybean production, is heaviest in areas of the state where aquifers are generally least vulnerable to contamination.

- Preliminary results on the effect of selected quaternary ammonium cationic surfactants (QAC) on the movement of pesticides in coarse, sandy soils show that benzylidimethyl-decyldiammonium chloride significantly increased the adsorption and reduced the leaching of atrazine. The findings suggest that QACs have the potential for reducing leaching of pesticides into groundwater.

- A solid phase extraction technique, being studied by Survey chemists, is showing promise for large volumes of samples to be extracted for pesticide determinations with a minimum of glassware, organic solvents, and extract cleanup.

Waste Management

- ISGS researchers have found that tritium is a good indicator for monitoring migrational pathways for landfill leachate. Also, data show that carbon 13 and deuterium are enriched in landfill leachate and can be thus used as indicators in studying leachate contamination. This is part of an effort to determine which set of isotopic analyses will yield the most useful information for tracing landfill gases and leachates.

- Compost facility designers were alerted to the potential for leaching of potentially hazardous constituents from yard waste and finished compost in an article published by ISGS researchers in an environmental journal.

- Recent efforts to provide technical assistance in landfill siting have focused on finalizing the maps of Will County and beginning the mapping for McLean

County. General surface topography, bedrock topography, thickness of glacial materials, and sand and gravel isolith maps will be published for Will County. There will also be a series of "depth slice" maps and of "elevation slice" maps illustrating the distribution of coarse and fine grained materials from the surface to a depth of 200 feet.

• The Geographic Information System (GIS) is being used for the project, County Screening for Landfill Siting. Well data being entered into the ISGS computer database come from Adams, Carroll, Cook, De Kalb, Du Page, Grundy, Kane, Kankakee, Kendall, La Salle, Macon, and McLean Counties as well as parts of De Witt, Piatt, Ford, and Iroquois Counties. To date, the project team has entered 206,663 descriptions from geologic units encountered in 37,511 wells.

• During the first half of the fiscal year, the ISGS continued to provide expert testimony to the Siting Commission for Disposal of Low-Level Wastes in Illinois. Recently, the ISGS began a technical assistance program for the Illinois Department of Nuclear Safety regarding development of the Martinsville site for low level, radioactive waste disposal.

• A report discussing the complex, but predictable, lithologic sequences at the Martinsville Alternative Site for Low-Level Radioactive Waste Disposal is in review.

• The ability of alkaline, fluidized-bed combustion (FBC) wastes to neutralize acidic coal slurry wastes from coal preparation plants is under investigation. During the report period, aqueous leachates were collected from laboratory leaching experiments and outdoor weathering experiments of five FBC wastes. The samples were analyzed for pH, Eh, alkalinity, four anions and 30 elements.

Earth Hazards and Geotechnical Studies

• The Office of Surface Mining (OSM) awarded a contract to Northern Illinois University (with a subcontract to ISGS) for monitoring and evaluating the effects of longwall mine subsidence on aquifers in Illinois. The study is one of two projects picked in the United States by the Office of Surface Mining for possible formulation of national regulations concerning water replacement for land affected by longwall coal mining.

• Monitoring the effects of longwall subsidence continued. In one study area, the final position of many surface points showed permanent location changes of as much as 1.5 feet in the direction of the longwall mining operation and that surface crack development may extend as much as 38 feet deep.

• A report summarizing 4 years of a UI-UC study revealed that the areas needing mitigation over longwall panels are only 1 to 2 acres per panel. Soybean yields were as high in the mitigated areas as areas unaffected by subsidence. Corn crop yields, which reacted more to the weather conditions, had a 19% reduction of yield in the mitigated areas.

• Using Time Domain Reflectometry to monitor mine subsidence, ISGS and Northwestern University investigators developed a method to differentiate tensile and shear movements in the rock mass through monitoring of coaxial cables grouted into boreholes.

• The Illinois Mine Subsidence Insurance Fund has continued to support a computerized database that now contains information on about 4,800 claims covering both mine subsidence and non-mine subsidence damage for the entire state.

• Transfer of technology regarding earth hazards and geotechnical studies continued. Two visitors from a South African corporation were guided on tours of subsidence research and mitigation sites. In a separate effort, information on new mine subsidence insurance claims was entered into the ISGS Computer-Assisted Directory; 5,230 records are now in the database.

• Also, 16 more papers were released in the Illinois Mine Subsidence Research Program (IMSRP) reprint series. During the year, requests for IMSRP publications or the IMSRP bibliographic database were received from New Mexico, Kentucky, Ohio, England, Australia, Wisconsin, and Michigan.

• Field visits were conducted to Wabash Valley sites of "paleoliquefaction features" identified by the USGS. The Indiana and Illinois Geological Surveys issued a position paper on the features, indicating that their logical cause was seismic activity associated with one or more large earthquakes in the Wabash Valley seismic zone between 2,250 and 7,500 years ago.

• A preliminary earthquake risk map of southern Illinois was prepared for a joint FEMA-IESDA earthquake exercise. The map depicts areas that may be susceptible to landslides, liquefaction, or enhanced ground shaking.

• A total of 221 landslides were identified and classified along segments of the bluffs of the Ohio and Mississippi Rivers in the New Madrid Seismic Zone in southern Illinois. Stability analyses of three representative landslides indicate that they could be triggered by earthquake loadings similar to those generated by the 1811-1812 New Madrid earthquakes.

• The ISGS indoor radon database has been updated. The mean indoor level of radon in Illinois is near 4 pCi/L—the guideline level of the U.S. Environmental Protection Agency. Yet less than 1% of the measurements taken in Illinois exceed 20 pCi/L.

• ISGS, working with ISWS, provided timely information to Harza Engineering and the U.S. Army Corps of Engineers on the nature of the materials surrounding the flooded Chicago freight tunnels. Maps and cross sections supplied by ISGS were useful for confirming that the tunnels were mainly located in saturated clays that have low hydraulic conductivities, so that rapid dewatering would not result in failure of tunnel floors or walls during pumping.

GENERAL AND BASIC RESEARCH Geologic and Topographic Mapping

• *Geologic Mapping for the Future of Illinois*, ISGS Special Report 1, was developed in response to Senate Resolution 881 in 1990 and 98 in 1991. These resolutions called for the ISGS to present the status, needs, and priorities for a statewide geological mapping program. The overall cost of mapping the state at the required scale of detail is estimated to be \$55 million

in 1991 dollars. Assuming a 50:50 match of federal and state funds totaling \$2.2 million per year, the program could be completed in 25 years. Contributions from counties, municipalities, and industry could reduce this time significantly.

- The National Geologic Mapping Act of 1992 was passed by Congress and signed into law by the President on May 18. It calls for federal funds to be matched by funds from other sources, commencing at \$15 million of federal support the first year and growing to \$25 million the fourth year. The authorizing bill must be backed by an appropriation bill to be effective.

- The Cooperative Geologic Mapping Program (COGEOMAP) in Illinois, co-sponsored by USGS and ISGS, has two parts: (1) mapping the bedrock geology of 7.5-minute quadrangles in southern Illinois, and (2) demonstrating the methodology for three-dimensional mapping of glacial deposits in the 30×60-minute Champaign quadrangle of central Illinois. Three more 7.5-minute quadrangles of southern Illinois were published: Creal Springs, Eddyville, and Stonefort. Also during the year, the first documentation of post-Cretaceous tectonic faulting in southern Illinois was recorded. In another study, evidence indicates that commercial tripoli deposits in southern Illinois are confined to areas of intensely fractured bedrock—a finding that supports the theory that low temperature fluids leached and silicified the fractured rocks.

- Computer-assisted methods to map subsurface geology are being developed, analyzed, and refined. Emphasis is on new data-handling techniques and new types of maps and visualization for near-surface glacial deposits (less than 500 feet or so) and other surficial materials. To date, about 134,000 well locations with lithologic descriptions have been automated. The effort is being funded in part by the UI-UC Institute of Environmental Studies.

- The state's topographic map database is being revised and updated by the USGS with the cooperation of the ISGS. Of the 46 maps at 1:100,000 scale, all but one have been converted to topographic format. Also, for the 1:100,000-scale county map series, 58 maps have been published and five have been completed as topographic editions. Digital elevation data are available for a limited number of quadrangles.

Crustal Studies

- A high-quality seismic reflection profile that crosses the transition zone between the Reelfoot Rift and the Rough Creek Graben shows prominent structures, including the Shawneetown-Rough Creek Fault Zone, Hicks Dome, the Fluorspar Area Faulted Complex, and the Taft and Pennrile Fault Systems. The seismic data show that the Cambrian Rift System along the profile is a half graben that thickens to the southeast, in contrast to the northward-thickening geometry farther to the east in the Rough Creek Graben.

- Correlation of seismic reflection data with surface mineralization patterns shows that, in most cases, mineralized surface faults clearly cut basement or are splays from faults that cut basement.

- Recently acquired COCORP and proprietary seismic reflection data from the southern part of the Illinois Basin, combined with other geologic and geophysical data, indicate a west-northwest-trending Proterozoic crustal boundary lies beneath the 1.48-billion-year-old granite-rhyolite terrain within the area. The location of the boundary between the Wabash Valley Seismic Zone and the New Madrid Seismic Zone to the southwest may be a significant factor in the present seismicity of these two regions.

Basin Analysis

- Results of modeling tectonic basin subsidence indicate that it is controlled by three mechanisms: rifting, thermal subsidence, and an isostatically uncompensated mass in the lower crust.

- Four more regional structural cross sections were completed for the Illinois Basin during this report period. The total is now seven. These sections provide valuable information on the structural history and stratigraphic framework of the basin. During the course of the cross section project, wireline logs for about 225 drill holes in the basin were digitized.

- Application of sequence stratigraphic concepts of Upper Pennsylvanian cyclic strata in Illinois resulted in a modification of the Wanless and Weller cyclothem. The modified cyclothem is a stratigraphic unit, bounded by disconformities (marine-flooding surfaces). Many practical uses are indicated for this modified concept.

- The program plan of the Illinois Basin Consortium (IBC), which consists of the Illinois, Indiana, and Kentucky Geological Surveys, has been published. Work under this plan is well underway and includes participation by the USGS on several projects that focus on gas/fluid/rock interactions that have modified the basin through time. The effort by the USGS includes the purchasing of several high resolution seismic lines for use by the IBC.

- The structural geology and tectonics of the Rough Creek Graben were the focus of a guidebook published by ISGS for the next Annual Meeting of the Geological Society of America to be held in Cincinnati in October 1992.

Quaternary Investigations

- Two manuscripts dealing with the Quaternary geology of parts of Illinois are in review. "Fluctuations of the Lake Michigan Lobe during the Later Wisconsin Subepisode," was accepted for an honorarium volume in Sweden. "The Wedron Group," is in revision for external review. Both manuscripts aim for a better understanding of the sediment record and the glacial and postglacial history of the Lake Michigan Lobe Region. Such understanding helps in predicting the materials likely to be encountered in the subsurface of areas for which site-specific information is unavailable.

- Ostracodes and pollen from cores taken in Montgomery and Fayette Counties indicate a relatively dry phase occurred at the onset of the last glaciation. Other sites examined indicate that the glacial climate in Illinois at 38° north latitude about 18,000 years ago was similar to that of modern eastern Minnesota.

- Contacts were made with geoscientists in Arkansas, Louisiana, and Tennessee to establish reference sections of loess deposits for comparison and calibration of climate change effects across the Midcontinent.

- ISGS Quaternary geologists undertook field and office consultations with (1) ISGS scientists on applied mapping projects in Lake, McHenry, and Will Counties as well as on groundwater and wetlands studies in Champaign, Cook, and Du Page Counties; 2) State Museum scientists on geological mapping in Kankakee State Park and paleoecological reconstruction at Crystal Lake and Wedron; (3) USGS scientists on paleoclimate, lake-level history, and wetlands development in the Chicago area; (4) Argonne National Laboratory scientists on regional stratigraphy in that area of Illinois; and (5) Fermi National Accelerator Laboratory on geologic, geotechnical, and hydrogeologic questions. ISGS scientists also assisted industry consultants and others by providing information on Quaternary deposits for the siting of three facilities in the Chicago area and three special projects in the region.

Hydrogeologic Investigations

- Pristine fens in northeast Illinois are under evaluation for long term effects of urbanization on water quality. Chemical data indicate that anthropogenic contaminants such as sodium, chloride, and sulfate (probably from septic effluents) are entering groundwater that feeds into the fens and altering the plant succession from rare and endangered species to cattails. Shallow streams crossing the fens intercept incoming contaminants and protect parts of the fens.

Paleontology/Palynology Investigations

- The original manuscript on the conodont genus, *Lochriea*, has been revised. The redefinition of the genus makes it more useful as an age determinator of Mississippian rock units.

- Two manuscripts detailing palynological investigations have been submitted to outside journals. The first correlates major Pennsylvanian boundaries in the Illinois Basin with those in other areas. The second study establishes the causes of major floral changes that occurred at the Middle-Upper Pennsylvanian boundary; it concludes that the sudden change was caused by the northbound migration of the landmass across the paleo-equator and the resulting change in wind and ocean currents. Also, major glaciation in the southern hemisphere lowered the global temperature by a few degrees, and major reduction in atmospheric carbon dioxide had a harmful affect on the physiology of plants, especially the large coal swamp plants.

- Palynological correlation of the Dawson Springs Coal of Kentucky with the Buffaloville Coal of Indiana and the O'Nan Coal of Illinois shows the lower Middle Pennsylvanian coal to be more widespread than previously thought.

Geochemical Investigations

- Efforts are underway to establish the effectiveness of bacteria in biodegrading oil spills and altering hydrocarbons in subsurface reservoirs.

Mineralogic Investigations

- Berthierine, a rare clay mineral, is the raw material for 1,500- to 5,000-year-old Native American artifacts from northwestern Illinois. A sample found in the Ordovician Neda Formation near Sterling, Illinois, proves that the raw material came from the local area and not Portsmouth, Ohio, as earlier believed. An Illinois source thus alters the assumed pattern of dispersal through ancient trade networks.

- A mixed-layered kaolinite/expandable clay mineral is abundant in modern soil and at least three major paleosols at Thebes, Illinois. The modern and ancient occurrences allow a comparison of climates and rates of weathering during the present and last two warm periods between major advances of glaciers.

Computer Research

- An ISGS network of 15 Sun workstations, one Sun Server, four DEC workstations, and three Silicon Graphics workstations that communicate and share data is in place. The workstations replace the Prime 9955 computer, which was disconnected July 1, 1992.

- A 1:500,000-scale map showing 316,000 well locations of record in the state is in review. When released, the map will be available through the ISGS Open File Series. Color copies will be produced from the electrostatic plotter.

- Four Arc Macro Language programs were developed and refined for applications of the Geographic Information System (GIS). In the GIS tools competition at ESRI's annual meeting, the SCALEBAR program developed by an ISGS computer researcher won second place.

Scientific Support Services

- Analytical chemists analyzed samples from 16 different research projects during the report period. In total, 5,390 samples were analyzed and 31,248 determinations were made on those samples.

- During the report period, carbon and oxygen isotope analyses were completed on 792 samples; sulfur isotope analyses were performed on 620 samples; deuterium to hydrogen ratios were determined for 545 samples; and nitrogen isotope analyses were conducted on 481 samples. The analyses were completed for research projects at ISGS, UI-UC, and other agencies throughout Illinois.

- For geologists and archaeologists throughout Illinois, 130 radiocarbon age dates were determined. For ISGS landfill studies, 50 radiocarbon measurements were made of groundwater, landfill methane and CO₂, and landfill leachate.

- An estimated 1,500 X-Ray diffraction analyses were run for clay minerals, and 380 were performed for the determination of other minerals. The analyses were run for 41 projects concerned with coal ash, oil recovery, stratigraphic correlation, and other research; about 15% were for QA/QC.

- A comprehensive Chemical Hygiene Plan was produced for ISGS staff who work in laboratories. The plan ranges from standard safety procedures to what to do in case of an on-the-job injury.

TECHNICAL AND ADMINISTRATIVE SERVICES

- Vital operations support ISGS research and service:
- budgeting, accounting, and financial reporting
 - preparing and monitoring of contracts and grants
 - counseling and timekeeping for staff
 - coordinating searches to fill open positions
 - cataloging, searching, and locating library materials
 - receiving and distributing mail, commodities, and equipment
 - processing orders and shipping publications, maps, and other materials
 - maintaining the Information Office
 - conducting public field trips
 - overseeing media and legislative relations
 - fabricating, maintaining, and repairing scientific, office, automotive, and other equipment
 - overseeing automotive operations
 - arranging telecommunications
 - providing editing, graphics, typography, and photography for publications
 - duplicating publications
 - planning and supervising new construction and building renovations.

The Geological Records Unit, Geological Samples Library, and Reference and Map Library maintain the documents, data, and materials collected through decades of geological research and related activities. Collections housed in these facilities serve as a basic source of information for private industry, government agencies, and the general public.

Business and Financial Services Unit

- BFSU focused on budgeting, cutbacks, replacement of two key staff members, and reorganization of contract accounting work assignments.
- Numerous budget and reduction scenarios and options for necessary cuts were presented to management to meet FY92 and FY93 funding reductions.

Human Resource Office

- HRO coordinated or presented seven seminars for staff on personnel-related matters.
- A total of 57 searches for qualified staff were conducted, mainly on behalf of grants and contracts; 846 applications were received and processed.
- HRO handled a high volume of paperwork related to retirements, employment verifications, tax deductions, personnel evaluations, tuition and fee waivers, medical insurance forms, contract appointments, workers compensation reports, and new IDs.

Public Information Unit

- In the mail room, a new Pitney Bowes USPS/UPS scale was installed for economy and efficiency. Greater use of the USPS permit imprint also decreased costs and increased efficiency.
- In the Duplicating Shop, recycled paper is used whenever possible. This year, duplicating impressions totaled 1,560,715.
- Although acquisitions and circulation of materials decreased in the Library this past year, reference

questions and interlibrary loans increased greatly in tandem with the increases in literature searches, reference questions, visitors, and outside phone requests.

Public Liaison

- This office had a major thrust this past year of keeping government officials at all levels—municipal, county, regional, state, and federal—informed about the ISGS.
- Highlights of research and service were disseminated through a report written especially for the public; meetings with special interest groups; articles for magazines, newsletters, and journals; personal letters and visits; news releases and editorial commentaries; fact sheets; brochures; and exhibits.

Publications, Graphics, and Photography

- Output of original reports in ISGS series grew from 16 in 1990-1991 to 24 in 1991-1992. The most significant rise in production was shown in a new area, the ISG Open File Series.
- Last year's tally of 12 large format maps and cross sections increased this year to 16.
- Demand for the scientific photographer's skills continued to grow, as reflected by the increase from 4,800 to 8,280 photos taken over the last 3 years.

Technical Design Operations and Maintenance

- During the report period, 338 internal work orders and 268 verbal requests were filled for repair, fabrication, moving, maintenance, or other services.
- ISGS received 178 pieces of assorted office equipment from the Illinois Mine Subsidence Insurance Fund. Staff cleaned and repaired the equipment and moved it to replace antiquated office equipment.
- In the woodworking shop, 52 different types of workstations, tables, desk files, bookshelves, and map cases were constructed for staff.
- Shop activities included special design and construction work for equipment used in field and soil gas sampling, for hydrogeology and groundwater protection laboratory work, and for site preparation and hooking-up the Process Optimization Unit for making high-surface-area hydrated lime.
- The ISGS drill rig and operator were utilized for six ISGS projects during the year.
- The ISGS services and maintains records on the 25 ISGS vehicles and the 55 vehicles of the Illinois Natural History Survey. The ISGS operational cost for the fleet this year was a low of 10.9 cents per mile.

Educational Extension

- The ISGS hosted four geological science field trips, each held on a Saturday. One trip was to the Decatur area, another to the Pere Marquette State Park area, the third to the Cave-In-Rock and Rosiclare area, and the fourth to the Galena area. Of the 697 attendees, 154 were elementary, high school, and college students; and 81 were elementary, secondary, and college teachers. This educational extension program, which began in 1930, continues to be popular with school teachers, students, and the general public.

Geological Records and Samples Library

- The CONQuEST system of data transfer using the Vax workstation went online in January.
- With the cumulative entry of 16,503 records in January 1992, the third and last phase of the water well catch-up was completed. During the past 3 years, a water well task force has (1) applied the CONQuEST software program for data entry and printing of water summary sheets; (2) entered 58,106 permits and/or logs into the system; (3) consolidated the paper files into a retrievable file system; (4) improved data exchange with the ISWS; (5) assisted the Illinois Department of Public Health and some counties in implementing new rules for submitting data to state agencies; and (6) added 155 log books with new water well data to the ISGS collections.
- Oil well permits issued by IDMM increased from 1,610 in 1990-1991 to 3,072 in 1991-1992. Oil and water well plugging affidavits also increased.
- Processed drill hole records at the ISGS now number 342,026. Included are 132,320 geophysical logs.
- Visitors and staff to the Geological Samples Library referred to files 265 times and studied 848 sets

of samples, a significant increase over last year.

- The total footage of cuttings represented by samples at the Geological Samples Library is now 742,997,131 feet—more than half the distance to the moon!

- Nineteen cores of Ordovician and Cambrian rocks, totaling approximately 2,600 feet, were donated to the ISGS Samples Library by Panhandle Eastern Pipeline Company. The cores are from Champaign, Douglas, and Morgan Counties.

Capital Projects

- The \$630,000 Lab Upgrade Project of 20 laboratories in the Natural Resources Building was completed.
- A \$3.44 million upgrade of the Natural Resources Building is in the planning and development stage following the release of funds by the Capital Development Board. The ISGS and the Natural History Survey are working together on the project.
- For FY93, \$200,000 has also been appropriated to plan and develop an upgrade of the Applied Research Laboratory.

MINERAL RESOURCES AND ENGINEERING

ILLINOIS MINERAL INDUSTRY, 1990-1991

Mineral production and value in Illinois declined in 1991, according to preliminary data (fig. 1). The extent of the decline in value is estimated to be about 8% (table 1). Coal, oil, and industrial minerals all showed declining production and value. One possible exception is the clay industry, which employed 120,500 persons, 3,500 more than in the previous year.

The unusually high increase in clay production in 1990, as reported in the last annual report and in table 1 of this report, could not be verified by the U.S. Bureau of Mines (USBM). Responses to queries from the Illinois State Geological Survey (ISGS) indicate that the production of about one-half million tons of quarry tiles was erroneously reported in 1990; however, the USBM is unable to rectify the error. Clay production was probably much lower than reported in 1990, and thus by comparison, the clay industry in Illinois may have improved its performance in 1991.

As anticipated in the last annual report, all minerals except clay declined in production due to the effects of the recession and the amendments to the Clean Air Act in 1990. Mineral prices per unit also declined, including oil prices, which fell about 15% from the average 1990 level. The effects of the recession and the amendments to the Clean Air Act are expected to continue through 1992.

COAL

Illinois ranks high among the states with the greatest quantities of coal resources. In deposits of high energy bituminous coals, Illinois ranks first.

A significant portion, 50 billion tons, of the 180 billion tons of identified coal resources are comparable to coal currently being mined and thus classified by the ISGS as having a high potential for development. Much of it has a high sulfur content (3-5%). About 3.7 billion tons of the coal with high development potential has a relatively low sulfur content of less than 2.5%; the average sulfur content is approximately 1.5%. The lower sulfur coal continues to be mined preferentially. Interest in these resources has also heightened since passage of the amendments to the Clean Air Act in November 1990. Monterey Coal Company, for example, recently assessed the low sulfur coal reserves adjacent to its Monterey No. 1 Mine and plans to increase production from this coal.

The future of the coal mining industry in Illinois is uncertain. High and moderate sulfur Illinois coal can only compete in the market if delivered at a competitively low price. Fortunately, the characteristics of the remaining coal reserves and recent developments in mining technology should put Illinois coal into a good position, as far as price per unit energy contained in the coal is concerned.

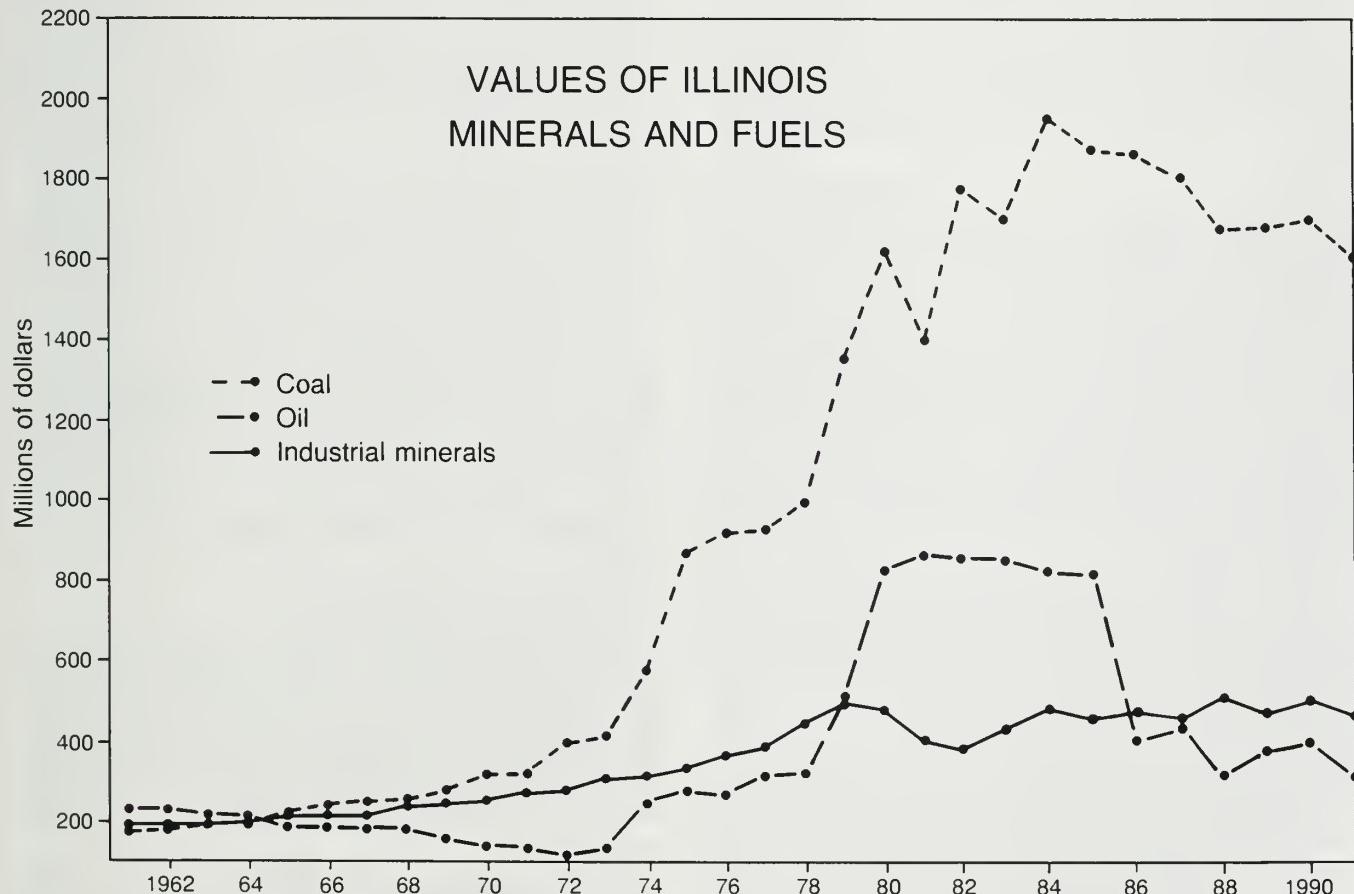


Figure 1. Value of Illinois minerals and fuels.

Table 1 Mineral production data for 1990 compared with preliminary data for 1991.

Minerals extracted	Unit	1990		1991		% change from 1990 to 1991	
		Quantity	Value (thousands)	Quantity	Value (thousands)	Quantity	Value
Fuels							
Coal	thousand	61,657	1,709,750	60,036	1,620,959 ^a	-2.6	-5.2
Crude oil	thousand bbl	19,954	406,462	19,069 ^a	326,843 ^a	-4.4	-19.6
Natural gas	thousand Mcf	677	1,428	466 ^a	1,011 ^a	-31.1	-29.2
Industrial and construction materials							
Stone ^b	thousand tons	62,700	283,100	58,000	262,300	-7.5	-7.3
Sand and gravel	thousand tons	36,866	167,259	31,700	150,400	-14.0	-10.1
Clay ^c	thousand tons	660	2,516	180	1,102	-72.7	-56.2
Metals, gemstones and other undisclosed ^d			54,352		47,196		-13.2
Total value of minerals extracted			\$2,624,867		\$2,409,811		-8.2

^a Estimated by Illinois State Geological Survey.

^b Dimension stone included with values that cannot be disclosed.

^c Excludes fuller's earth; included with values that cannot be disclosed.

^d Includes fluorspar, zinc, barite, peat, gemstones, fuller's earth, sandstone, and dimension stone for 1990 and 1991, and copper, lead, silver, tripoli for 1990 with no estimate for 1991.

Source: U.S. Bureau of Mines and Illinois Department of Mines and Minerals.

Illinois produced 60.0 million tons of coal in 1991, a slight decrease from the 61.7 million tons produced in 1990. The four leading coal-producing counties were Perry with 10.1 million tons, Saline with 7.9 million tons, Randolph with 6.3 million tons, and Franklin with 6.2 million tons—almost unchanged from recent years.

The 1990 amendments to the Clean Air Act (CAA) have started to affect the markets for high sulfur Illinois coals. An example of this is the decision by the Associated Electric Cooperative of Missouri to stop burning high sulfur Illinois coal from Peabody's Marissa, Baldwin, and River King No. 6 mines at their New Madrid station. In 1994, they will switch to low sulfur coal, also produced by Peabody in Wyoming's Powder River Basin. About 350 mining jobs will eventually be lost. Competition among Illinois coal producers is intense as they vie to replace relatively higher sulfur coal with lower sulfur coals to meet the first phase requirements of the 1990 CAA amendments by January 1995.

Some Illinois coal companies are following Peabody's example in geographic diversification to retain their share of the changing coal market. Zeigler Coal Company has announced plans to purchase Shell Mining as part of their search for lower sulfur coal reserves. Both companies have contracts to supply coal to Georgia's Southern Cooperative Services. Zeigler can thus supply low or high sulfur coals, as needed.

Individual coal companies can secure their future by diversification, but loss of markets for Illinois coal cannot be prevented, certainly not in the short run. In the long run, the CAA amendments can open markets for low cost Illinois coal and limestone.

Despite difficult market conditions, several mines opened. Freeman United Coal Mining Company reopened its Crown III underground mine in Macoupin County and began production in August 1991; the mine had been idle since September 1987. The Conant underground mine in Perry County was opened by Arch of Illinois through its subsidiary Cutler Mining Company. In Williamson County, the Southern Illinois Mining Company opened its No. 2 mine. Zeigler Coal Company idled its Old Ben No. 21 mine in Franklin County in November 1991; but since the company is actively seeking buyers for coal from the mine, the mine is being kept in good condition.

Exploration of potential new mining sites and areas adjacent to existing mines for future development was conducted by Consolidation Coal Company in Clark and Randolph Counties, Kerr McGee Coal Corporation in Hamilton County, AMAX Coal Company in Perry County, MAPCO/White County Coal Company in White County, and Vermilion Energy Inc. in Vermilion County.

Coal Database Management

Coal Exploration Records, Frankie Coal test drilling for exploration and development remained steady in 1991. Thirteen companies filed 680 Test Hole Record and Plugging Affidavits from 18 different counties with the Illinois Department of Mines and Minerals. Copies are filed with the ISGS. During 1988, 1989, and 1990, the coal industry filed 637, 889, and 674 records, respectively.

About 103 of the holes drilled in 1991 are far enough away from active mines to be classified as exploration holes. This is a significant decrease from

the 222 exploration holes drilled in 1990. The other 577 holes drilled in 1991 are located near active mines in southern Illinois and thus classified as developmental drilling. Four counties—Saline, St. Clair, Perry, and Williamson—accounted for 451 of the 680 test holes.

The Coal Section received a donation of more than 20,000 drill hole records from Midland Coal Company. Midland ceased operation of its coal mines in western Illinois in 1991. The drill records cover both exploration and mine development, and they provide detailed information on coal thickness and depth in several counties west of the Illinois River where the company was active for many years. These records might otherwise have been lost with the dissolution of Midland's land office. Efforts are underway to secure drill records of other companies that have retreated from Illinois in recent years.

Coal Quality Database, Harvey, C. Treworgy The files and programs in this database were transferred from the Prime minicomputer to the new Sun workstation. Because the Sun uses a different Unix operating system, the existing programs will not operate at this time. Required revisions of the programs will be made in the near future.

Management of Data on Illinois Coal, C. Treworgy, Coats, Skurnak, Zhu Work was completed on our FY91 grant from the U.S. Geological Survey (USGS) to collect and compile stratigraphic information on Illinois coals. During this period we compiled and correlated stratigraphic data for 465 coal test holes. As in past years, these data were entered into our computer database on coal stratigraphy as well as into the National Coal Resource Data System.

Coal Mine Information System, Treworgy, Bargh, Coats The Illinois Coal Mine Maps that show active and abandoned mines on 1:100,000-scale, county base maps were updated with maps obtained from active coal mining companies. The accompanying directories were redesigned so that it is possible to find the entries listed under mine name or location, as well as the unique mine index numbers that key the maps. There are 80 maps and directories for 73 counties in the series, and this 1991 update is now available to the public.

The Springfield East 7.5-Minute Quadrangle mine map (scale of 1 inch = 2,000 feet) and the accompanying directory were completed. This is a pilot project for a new series of much more detailed mine maps than are available now. The map shows the mine boundaries and indicates methods of mining used; mine outlines are displayed relative to types of land use and other important surface features. The directory lists mine location, index number, coal seam, years of operation and mine ownership. Currently, the map and directory are undergoing editorial review.

Coal Mining Geology

Ground Stability in Partial-Extraction Mining in the Springfield Coal, Damberger, DeMaris (ISGS); Chugh,

Phillips, Singh (SIU-C) This cooperative study with the Department of Mining Engineering at Southern Illinois University at Carbondale (SIU-C) was aimed at characterizing ground conditions in underground coal mines. A primary goal of this work is to improve the predictability of unstable roof and floor sequences in advance of mining. Basic roof and floor rock successions were developed on the basis of in-mine exposures and drill core descriptions. These successions allow the geological risk factors characteristic of each roof or floor succession to be identified during the evaluation of drill cores. The report was completed and is being reviewed. The project was supported by the Illinois Mine Subsidence Research Program.

Strike-Slip Fault at Crown II Mine, Nelson, DeMaris A strike-slip fault has been mapped across the mine; it appears to be unrelated to previously known structural features in the area. Resolution of map details and further interpretation of movements need to be completed before the manuscript is ready for review. Final mapping was completed in the fall of 1990; analysis is ongoing.

Nature and Distribution of Coal Balls in the Herrin Coal, DeMaris, Cahill The goal of this project is to refine and clarify the utility of our prediction model for occurrences of coal balls; the model was developed previously for occurrences in Franklin County. In most mines where they occur, the coal ball areas hinder mining. Data were gathered on peat-to-coal compaction ratios from a coal ball core. Recent field mapping of coal ball areas in an underground mine provided contrasting data from a different geologic setting for coal ball occurrences that hinder mining.

Coal Resources

Availability of Coal Resources in Illinois, C. Treworgy, Bargh, Coats The purpose of this project is to identify how much of the state's coal resources are available for development (e.g. free of technical and legal restrictions to mining). Factors limiting the availability of coal are being identified and evaluated through studies of sample areas located throughout the coal field. Evaluation of the first study area, the Middletown Quadrangle located just north of Springfield, was completed during this report period; a final report is now undergoing peer and administrative review. Preliminary results indicate that less than 60% of the coal resources are available for mining and possibly less than 25% of the resources may actually be recoverable. Factors limiting the availability of coal in the study area include weak roof and floor rock, thin bedrock cover, unfavorable stripping ratios, thin coal, and surface features such as cemeteries and interstate highways.

Coal Resources of the Dekoven and Davis Coals in Southeastern Illinois, Jacobson, C. Treworgy The Davis and Dekoven coal seams have contributed significantly to coal production in southern Illinois, southeastern Indiana, and western Kentucky. Except for a study of surface minable coal resources more than 30 years ago,

the coal resources in these two coals have never been studied systematically in southern Illinois. This project will fill the areal gap between the outcrops of the coals along the southeast edge of the Illinois Basin Coal Field and the occurrence of the correlative Seelyville Coal in east-central Illinois, as reported upon in 1981.

Part 1 Gallatin and Saline Counties Editing and drafting of the figures and plates for this report were nearly completed; publication is planned for the next report period.

Part 2 Approximately 400 more drill hole records were added to the database, which was transferred from the phased-out Prime minicomputer to a Sun workstation. Work began on adapting an ARC/INFO program, recently written for another coal resource study for this project.

Coal Characterization

Clay Mineralogy of Coal-Related Strata, Hughes, DeMaris, Moore, White This research is aimed at understanding environments of coal formation, the effects of clays on coal mine stability, and ways in which the minerals in coals can be exploited to better use coal and associated resources. A round-robin analysis of the mineral content of low-temperature ashes from two standard coals was performed for the USGS to support their effort to standardize analytical procedures. Also, an investigation of the cause of ash fusion anomalies was carried out for Amex Coal Company.

Characterization of the Surface Properties of Illinois Basin Coals, Demir, Harvey, Lizzio The purpose of this project, funded by the Illinois Coal Development Board, is to determine surface properties (internal surface area, porosity, surface charge, and surface chemical structure) in fresh and oxidized states of eight coals in the Illinois Basin Coal Sample Program. These properties influence most processes involving preparation and utilization of coal.

Analytical results to date indicate significant variations in the surface area and pore-size distribution of the coals. These observed differences may be useful in predicting differences in physical-chemical behavior of these coals during coal cleaning, conversion, and combustion processes. A 2-month exposure of the coals to air oxidation at room temperature caused the pore volume to decrease somewhat, primarily in the macropore range (500-10,000Å). This suggests that oxygen compounds form easily on the surface of the macropores, probably because of the loss of moisture and the resulting exposure of pore walls to oxidation. Oxygen on the coal surface was found to be involved in hydroxyls with hydrogen bonds of various strengths. Aromatic (ring structure based), aliphatic (chain structure based), and aldehyde groups were observed on the coal surface.

Maceral Classification of Illinois Coals, Harvey Industrial interest in the maceral composition of commercial coals is of increasing importance as coal macerals were recently used to characterize coal "type"

by the United Nation's Economic Commission for Europe (UNECE). Yet, maceral analysis is not reproduced well by microscopists around the world. As a part of the coal characterization program, a review of the standard maceral classification was undertaken. It was found that several criteria used to subdivide the vitrinite group of macerals were not entirely logical. Consequently, the criteria were probably not being applied the same all the time; this contributes to variance in the results between different laboratories.

Dr. Harvey drafted a revision of the existing ASTM classification, including definitions, based on vitrinite group macerals that had previously been described by the International Committee for Coal Petrology. The revised classification and definitions are currently being considered by the members of the appropriate ASTM subcommittee and other coal microscopists.

Behavior of Sulfur and Chlorine during Coal Pyrolysis/Combustion: Experiments with Pyrolysis/Gas Combustion Apparatus and Quadrupole Gas Analyzer, C.-L. Chou, Hackley, Donnals, Cao, Ruch This project, under contract with the Illinois Clean Coal Institute (ICCI; formerly CRSC), includes a study of the evolution of sulfur and chlorine during pyrolysis and combustion of Illinois coals. The study will contribute to a better understanding of the mechanism of boiler corrosion caused by sulfur and chlorine in coal.

Experiments to date indicate that chlorine in Illinois coals is released solely as HCl, not as NaCl, during pyrolysis and gas combustion. The HCl release profiles of coal IBC-109 of the Illinois Basin Coal Sample Bank show a broad peak between 250° and 600°C with a maximum at 445°C. In contrast, the sulfur release profiles of coal IBC-109 show three peaks: the sulfur released at about 370°C may be derived from elemental sulfur; the main peak at 475°C corresponds to the release of organic sulfur; and the third peak at 600°C results from the decomposition of pyrite. The sulfur species formed in the combustion gas are controlled by the oxidizing conditions in the combustion chamber. Sulfur dioxide is the predominant sulfur species observed. In some experiments, during the major release of volatiles between 450° and 550°C, a reducing condition occurred, which resulted in the formation of such sulfur species as carbonyl sulfide (COS) and hydrogen sulfide (H₂S).

Some of the results were presented at the National Meeting of the American Chemical Society in San Francisco in April.

Thermogravimetry-Fourier Transform Infrared Spectroscopy of Volatile Compounds Released during Coal Pyrolysis, C.-L. Chou (ISGS); W. P. Pan, D. Shao (Western Kentucky University) In this study for the ICCI, the ISGS and Western Kentucky University cooperated to investigate the composition of gases during pyrolysis of four Illinois coals (IBC-103, -105, -106, and -109). The thermogravimetry (TG) and Fourier transform infrared (FTIR) spectroscopy technique was used. The weight loss behavior of coals during pyrolysis was observed using the TG technique.

Significant weight loss occurred for the coals in the temperature range of 350°C to 850°C with different maximum rates. Most of the gases evolved from the coals have been identified by the FTIR technique and the relationships between the amounts of gases evolved and heating temperature have been established. The amounts of sodium and chlorine retained in the pyrolysis residues of the four coals were determined by neutron activation analysis. Gas evolution profiles of sulfur (H_2S , SO_2 and COS), chlorine (HCl), and nitrogen (NH_3 and HCN) species were determined. Similar release profiles of HCl and NH_3 support an interpretation that chlorine and nitrogen are closely associated in coal. The evolution pattern of carbonyl sulfide (COS) resembles that of CO, and thus indicates that carbonyl sulfide may be formed by reaction of H_2S with CO in the gas phase.

Synchrotron X-Ray Fluorescence Microprobe Study of Cleat Calcite in Illinois Basin Coals, C.-L. Chou (ISGS); Kolker (University of Nebraska) A suite of cleat calcite from the Herrin, Springfield, and Colchester Coals in Illinois was analyzed for trace elements by using the synchrotron XRF microprobe facility at the Brookhaven National Laboratory. The results are used to calculate the compositions of the calcite-precipitating solutions based on elemental distribution coefficients.

The compositions of these solutions were found to be different from that of seawater but within the range of groundwater. Thus, cleat calcites were probably precipitated from meteoric fluids in the coal seams. A paper describing results of this research was submitted to the *Journal of Geology*.

Graphic Values for Some Organic Constituents of Beneficiated Coal Samples, Kohlenberger, Lytle, Kruse, Chaven This project was sponsored by the ICCI and the U.S. Department of Energy (USDOE). Sample IBC-101 from the Illinois Basin Coal Sample Program was separated, using froth flotation, into fractions of varying ash content. Each sample was analyzed for forms-of-sulfur, proximate, ultimate, and Btu analyses, and the results were computerized to form a database. Then, each of the organic properties of the coal was plotted against ash content.

For IBC-101, each of the organic properties (Btu, organic sulfur, volatile matter, fixed carbon, carbon, hydrogen, and nitrogen) forms a straight line with the percentage of ash. These relationships make it possible to estimate all of these values from ash and total sulfur contents. This method also permits a more accurate evaluation of mineral matter; volatile matter in both the mineral and organic phases; oxygen addition during ashing; inorganic sulfur that is mistakenly considered organic sulfur by ASTM analysis; and inorganic carbon, hydrogen, nitrogen, and fixed carbon.

Other coals may or may not behave in the same way. There is no guarantee that other methods of concentrating or removing mineral matter would produce the same results.

Isotopic Characterization of Organic Sulfur in Different Fractions of Coal and Coal Macerals, Hackley, Cao (ISGS); Palmer (SIU) There are primarily two sources of organic sulfur in coal, original plant sulfur and secondary microbial sulfide sulfur. Researchers have hypothesized that since there are two isotopically distinctive sources, the different organic sulfur compounds in coal may have different isotopic signatures, reflecting the two primary sources of sulfur.

To help answer this question, SIU-C supplied samples that have been physically and chemically separated (by relatively mild processes, e.g. low temperatures) into different fractions containing different groupings of organo-sulfur compounds. Isotopic analysis of the organic sulfur isolated from the different fractions of each sample was recently completed. After SIU-C staff supply additional information on the chemical and physical treatment of these samples, the results will be interpreted.

Coal Cleaning: Physical and Microbial

Production of Superclean Coal by Wet-Grinding and Selective Flocculation, C.-L. Chou, Woodward, Chaven A method to remove both sulfur and chlorine from Illinois coals by wet-grinding and selective flocculation was developed with the support of the ICCI. Various polymeric flocculants were tested to determine their selective flocculation performance. The acidity of the slurry and the flocculent dosage were critical factors for effective separation of coal from mineral particles. The final report was released as ISGS Open File Series 1991-9 in February 1992.

Removal of Chlorine from an Illinois Coal by Wet-Grinding and Water-Leaching, C.-L. Chou A process development study for the removal of chlorine from a high chlorine Illinois coal (IBC-109, 0.42% chlorine on dry basis) by wet-grinding the coal to 80% -200 mesh, and subsequent water-leaching, was completed. The process has four stages: (1) crushing the coal to 80% -6 mesh; (2) wet-grinding the coal in a stirred ball mill to generate a coal slurry of 80% -200 mesh; (3) dewatering the slurry to generate a filter cake; and (4) leaching the filter cake with tap water at several temperatures to remove the chlorine remaining in the filter cake.

The chlorine content in the filter cakes of five wet-grinding runs was 0.28% to 0.32% (a chlorine reduction of 24% to 33%). A filter cake generated by grinding with hot water was leached with water at 93°C for 10 minutes, and its chlorine content was reduced to 0.21% (a 50% reduction).

A paper with this title is to be published in the Proceedings of the Ninth Annual International Pittsburgh Conference, October 12-16, 1992.

Gasifier Feed, "Tailor-Made" from Illinois Coal, Ehrlinger, Lytle, Kohlenberger, Lizzio, R. Frost, Brewer The purpose of the project is to generate an ideal fuel for a slurry-fed, integrated gasification, combined cycled (IGCC) gasifier. Co-investigators with ISGS include Illinois Coal Association, Williams Technology,

and Destec Energy. The presence of sulfur in coal has not been a detriment in IGCC technology, as sulfur is recovered as salable elemental sulfur. The product from fine coal flotation is a slurry that is also the feedstock for the slurry fed gasifier, and thereby eliminates the grinding or drying steps traditionally associated with coal supplies for gasifiers.

The ISGS generated actual and theoretical products for gasifier simulation. Several actual coal slurry products generated from beneficiation of waste streams of coal-washing plants have been submitted for rheological study. Destec has developed heat rate data that suggest targets for production grades and particle-size analyses. A higher plant efficiency is anticipated for beneficiated slurry feeds from Illinois coal, and lower CO₂ emissions per kilowatt hour, as compared to those of western coals.

Pumpability tests have been completed. The products that have been submitted are similar to those pumped by Williams Technology in their 5,000,000-ton-per-year, 273-mile pipeline in Arizona and Nevada. They anticipate no pumpability problems.

Carbonation as a Binding Mechanism for Coal/Calcium Hydroxide Pellets, Rapp, Lytle, Hackley, Moran (ISGS); Berger (UI-UC) In this ICCI funded project, the ISGS is investigating the pelletization of fine coal with calcium hydroxide, a sulfur-capturing sorbent. The objective is to produce a readily transportable fuel that will be in compliance with the recent amendments to the Clean Air Act. Carbonation, or the reaction of carbon dioxide with calcium hydroxide to produce a binding matrix of calcium carbonate, is being investigated as a method of hardening pelletized coal fines and of improving the economics of pelletization.

Results indicate that carbonation significantly improves pellet quality and serves to "weatherproof" the pellets. For pellets formed with a 2.3/1 Ca/S ration of calcium hydroxide, sulfur captures of greater than 70% have been achieved in laboratory tests conducted at 850°C, a temperature in the range of operation for fluidized-bed combustors.

This research could improve the marketability of the approximately 5% of Illinois' annual coal production that is currently discarded because mechanized mining procedures leave it too fine to be acceptably transported commercially.

Fine Coal Flotation of Plant Waste: An In-Plant Comparison—Column Versus Sub A Cells, Ehrlinger, Lytle, Brewer, Kohlenberger This project was funded by the ICCI and conducted in the Kerr-McGee plant at Galatia, Illinois, in cooperation with the Deister Concentrator Company. A column 30 inches in diameter and 35 feet high was provided by Deister and intermittently operated by ISGS staff for more than 1 year.

The column provided an improved concentrate with respect to grade of product, improved recovery of energy, and less power consumption over the conventional froth flotation presently used in the plant. A final report submitted in the spring of 1992 summarizes the impact of this technology.

The concentrate grades made by column flotation are regularly more than 13,000 Btu/pound, have less than 9.0% ash, and contain more than 90% of the energy units from the original coal waste slurry. In general, power requirements for operating the Sub A cells were higher than for operating the flotation columns. Reagent consumption, however, was higher for the column cell. More contact time was required for the column cell than for the sub-A cell.

Static Tube Flotation Tests, Khan, Lytle The purpose of this project was to test a static tube flotation column for its effectiveness in recovery of coal from the fine effluent stream of an Illinois coal preparation plant. The project was funded by the ICCI and subcontracted to the ISGS by Praxis Engineers of California. For the test, a static tube column was assembled, erected, and commissioned at the ISGS Applied Research Laboratory. Assistance was provided by the inventor, Dr. Yang of MTI in Houghton, Michigan.

Twenty barrels of fine effluent coal were collected for the tests. The samples contained large quantities of clay and were considered difficult to clean. More than 90 flotation tests were carried out under various conditions determined by Dr. Yang and Vas Choudhry of Praxis Engineers. Cubical and orthogonal test matrices were used. The tests showed that a product similar to the one achieved in a subaeration cell after successive cleaning can be achieved in a column in a single step. The reagent consumption of the column was higher than that of a subaeration cell.

Coal Cleaning: Chemical and Thermal

Integrated Methods for Production of Clean Char and Its Combustion Properties, DeBarr, Rostam-Abadi In the past several years, numerous research programs have focused on producing premium liquids by mild gasification of coal. The principal product of mild gasification processes (about 60-70% by weight) is a char that still has a considerable amount of sulfur. Reducing the sulfur present in the solid could potentially create a market for char as a utility fuel that could be fired directly or as a coal-char blend. The low sulfur char could also be an ideal feedstock for production of carbon adsorbents and/or metallurgical coke.

The objective of this ICCI-funded program is to produce chars that have sulfur contents at least 50% lower than those of the parent coals, and that, at a minimum, emit less than 2.5 lbs SO₂/MMBtu during combustion. This will be accomplished using an integrated process that combines physical coal cleaning, mild gasification, and char desulfurization.

This cooperative project involves the ISGS, the University of North Dakota Energy and Environmental Research Center (UNDEERC), and the U.S. Environmental Protection Agency (USEPA); it is cost-shared with the USEPA and the USDOE through UNDEERC.

In experiments conducted under nonoptimized conditions, the total sulfur contents of six coals selected from the Illinois Basin Coal Sample Program were reduced on average 58%, corresponding to a reduction of more than 60% in SO₂ emissions. Physical coal

cleaning, mild gasification, and char desulfurization reduced the SO₂ emissions of two of the coals nearly 70%. Chars prepared from four of the six coals tested had SO₂ emissions of less than 2.5 lbs SO₂/MMBtu. The average yield of low sulfur char obtained after mild gasification and desulfurization was nearly 64% by weight of the original coal.

Dissolution of Sulfur from Coal by Solvent Extraction, M. Chou, Lytle, Ruch, Kruse, Chaven, Hackley, Hughes, Harvey, Frost (ISGS); Buchanan (EIU); Stucki (UI-UC); Huffman and Huggins (UK) In this study, supported by the ICCI and the USDOE, a chemical coal desulfurization process developed by Midwest Ore Processing Company, operating at 120°C and using perchloroethylene (PCE) extraction, was tested on Illinois coals (1) to confirm and possibly improve organic sulfur removal from high sulfur Illinois coals by using PCE extraction or extraction with other reagents; and (2) to verify that ASTM analysis is an adequate method for PCE process evaluation.

Midwest Ore's results have been repeated on fresh IBC-104 coal. Oxidation of coals was found to affect some subsequent PCE desulfurization. Elemental sulfur and some oxidized forms of organic sulfur are amenable to removal by PCE desulfurization. Ohio 5/6 coal more readily produces elemental sulfur than Illinois coal during oxidation. The higher elemental sulfur content produced in the coal results in an apparent higher ASTM organic sulfur removal by PCE extraction. This is misleading since the elemental sulfur produced during air oxidation appears to originate mainly from pyrite oxidation.

Still underway are experiments to show that the source of some elemental sulfur produced from proprietary oxidant-oxidation may partially come from organic sulfur. PCE-treated coals contain high chlorine content; however, an effective dechlorination procedure discovered for PCE removal yielded a coal with a chlorine content as low as 0.03%.

Coal Wastes

Land Application Uses of Hennepin Dry Scrubber Byproduct Materials: Procurement, Characterization, and Submission for Testing, Ehrlinger, Dreher, Roy, Lytle, Kruse Dravo Lime Company is studying the application of dry scrubber byproducts to agriculture, highway construction, and mine reclamation. The ISGS is participating in the study by characterizing samples of fresh sorbent, spent sorbent, and feed coal from the Illinois Power Company's Hennepin power plant. The ISGS role is to compare the concentrations of chemical elements in the feed coal with those in the sorbent, and to determine what proportions of the elements are captured by the sorbent during combustion. The required samples have been collected, prepared for analysis, and are now being characterized.

Coal Combustion

Development of High-Surface-Area Hydrated Lime for SO₂ Control, Rostam-Abadi, Moran, Lordgooei, Eidel, Lytle, Cooper, Donnals The ISGS has conducted six

years of research in developing a high-surface-area hydrated lime (HSAHL) process for use in stack gas sulfur removal. The process has been successfully scaled-up from a small, laboratory unit to a batch, bench-scale hydrator (5-7 lbs/batch), to the present continuous process optimization unit (POU) operating at 20 to 100 pounds per hour. Pilot-scale tests conducted with the HSAHL under conditions of burning high sulfur coals have achieved up to 90% SO₂ capture in various dry sorbent injection systems. These removals are adequate to bring Illinois coals into compliance with acid rain legislation goals for the year 2000 (1.2 lb SO₂/MMBtu).

Cost of the HSAHL has been projected to be \$10 to \$25 per ton higher than the cost of commercial hydrated lime. Given these estimates, the cost of sulfur removal (\$/ton SO₂) in dry sorbent injection systems would be about \$150 to \$200 for the HSAHL versus \$250 to \$300 for the commercial hydrate (sorbent and disposal costs only). Utilities burning high sulfur Illinois coals could save \$0.5 to \$6 million per year (depending on plant size, ranging from 100-500 MW) by using HSAHL in place of the commercial product.

Since 1986, the project has been funded by the Illinois Coal Development Board (ICDB) and Coal Industry Committee (CIC) through the ICCI. In FY91 and FY92, the ISGS received two Governor's Challenge Grants from the Illinois Department of Commerce and Community Affairs to advance the development of the HSAHL process and facilitate the transfer of this technology to the commercial market as rapidly as possible in order to preserve or increase the use of Illinois coal by utilities.

The POU (20-100 lbs/hour) was designed, built, and tested. It will now be used to generate design, construction, and operation data necessary for the private sector to scale-up the process to a commercial level. The data generated during the screening and shake-down tests of the POU provided adequate information to decide on major equipment for a 1-ton-per-hour HSAHL pilot plant.

Patent applications have been filed in the United States, Australia, Canada, Japan, and Europe. Research Corporation Technologies (RCT), a marketing and licensing organization in Tucson, Arizona, has accepted the responsibility for patent application and defense, marketing, and licensing for the ISGS invention. Dravo Lime Company and Kennedy Van Saun (KVS), manufacturers of commercial hydration plants, are industrial participants in the project. RCT is negotiating the licensing terms with Dravo.

Dravo and KVS, working with the ISGS, have proposed to construct and operate a 1-ton-per-hour pilot facility for manufacturing 600 tons of HSAHL for testing. To date, the Illinois Coal Development Board, Dravo, and KVS have pledged \$2,500,000 to the program. Once the facility is constructed and commissioned, HSAHL will be available for testing at selected utilities in Illinois.

The ICCI has awarded the ISGS a 2-year development grant that enables the ISGS to continue operating the POU. Data generated and experience gained with

the operation of the POU and the pilot plant will contribute to better understanding of the technology and provide engineering data needed to design and construct commercial plants.

Fuels and Chemicals from Coal

Production of Carbon Molecular Sieves from Illinois Coal, Lizzio, Rostam-Abadi Carbon molecular sieves (CMS) have become an increasingly important class of adsorbents for application in the separation of gas molecules that vary in size and shape. The overall objective of this project, funded by the ICDB through the ICCI, is to determine whether Illinois coals are suitable feedstocks for the production of CMS and to evaluate the potential application of these products in commercial gas separation processes.

Chars were prepared from Illinois coal in a fixed-bed reactor under a wide range of pyrolysis and activation conditions. Chars having commercially significant surface areas of 1500 to 2100 m²/g were produced by chemical activation, using potassium hydroxide as the activant. These high-surface-area (HSA) chars had more than twice the adsorption capacity of commercial carbon and zeolite molecular sieves. The kinetics of adsorption of various gases (N₂, O₂, CO₂, CH₄, CO and H₂) on these chars at 25°C was measured. The HSA char adsorbed more N₂ than O₂ and had a N₂/O₂ selectivity comparable to that of a commercial Type 4A zeolite. The O₂/N₂ molecular sieve properties of a char prepared without potassium hydroxide were similar to those of a commercial CMS. Several chars also showed potential for efficient CO₂/CH₄ separation; both a relatively high CO₂ adsorption capacity and CO₂/CH₄ selectivity were achieved.

Pore-size distribution of selected chars was determined by equilibrium adsorption of CO₂, n-butane, and iso-butane at 0°C. The extent of adsorption of each gas corresponded to the effective surface area contained in pores with diameters greater than 3.3, 4.3 and 5.1 Å, respectively. Air Products, a world leader in development of industrial gas separations technology, will further characterize pound quantities of select chars at their facility in Allentown, Pennsylvania.

Integrated Production/Use of Ultra Low Ash Coal, Premium Liquids and Clean Char, Kruse, Carlson, Kohlenberger, Lizzio, Rostam-Abadi, M. Chou (ISGS); Snoeyink, Feizoulof, Assanis, Syrimis (UI-UC); Fatemi, Mahoney (Amoco) Production of ultra low ash coal is the first step in this integrated, multiple product strategy for utilizing Illinois coal. Approximately 8 pounds of low ash coal was separated from the crude reactor slurry produced for the ISGS by the University of North Dakota Energy and Environmental Research Center (UNDEERC). After treatment to remove the remaining meta-cresol, this material was subjected to mild gasification, and then activated with steam/carbon dioxide. A catalyst surface was added by oxidation. Progress this year involves completing the test phase in a diesel engine, initiating chemical adsorption studies, and further characterizing oxidized activated coal chars known to be catalysts.

The preparation of a two-cylinder diesel engine at UI-UC for testing ultra clean coal/diesel fuel slurry was carried forward into the current work. A 20% coal and 80% diesel fuel slurry was tested after the necessary modifications were made in the engine's fuel injection system. Tests indicate that the coal can successfully substitute for diesel fuel in the slurry. The fuel burned with slightly improved thermal and combustion efficiency at 2200 rpm and 75% load. The coal particles did not have an apparent effect on heat release profiles.

Preliminary comparative chemical adsorption studies were initiated with Calgon F-400 commercial activated carbon to establish baseline reference data. The changes in the surface properties that accompanied washing activated carbon with 1.0 M hydrochloric acid and 1.0 M nitric acid, oxidation with air at 300°C, and oxidation with boiling nitric acid were characterized by X-Ray Photoelectron Spectroscopy. Surface oxygen increased with oxidation as expected. Nitrogen is less abundant on the surface than in the bulk. Nitrogen binding energies suggest alkylamines, aromatic amines, and pyridine derivatives. Three sulfur species were seen in all samples, the binding energies of which correspond to mercaptans, disulfides, and thiophenes.

Technical Support Services

Illinois Basin Coal Sample Program, Kruse, Chaven, Ehrlinger, Rapp, S. Khan (ISGS); Vorres (ANL) The Illinois Basin Coal Sample Program (IBCSP) was initiated in 1983 by ISGS for the Illinois Coal Development Board. The program encompassed the Indiana portion of the Illinois Basin in 1986 when Indiana placed one of their coals (IBC-106) into the program and accepted a share of the program's annual maintenance cost. The IBCSP facilitates data comparisons among laboratories conducting basic and applied research on Illinois Basin coals. Samples are selected primarily to meet the needs of coal research projects funded through the ICCI, but requests from all sources are honored.

The objectives are to (a) maintain the lots of coal under a nitrogen atmosphere to prevent oxidation and to record the condition of the coals; (b) fill orders monthly; (c) analyze representative samples twice yearly; (d) review and update records; (e) prepare reports to the ICCI and respond to recommendations of the IBCSP Advisory Committee; and (f) develop long-range plans, including a schedule of lots to be added or replaced.

The program has 11 lots currently from which to select samples: eight were collected in Illinois; three are from Indiana mines. Ten of the 11 lots are maintained in a nitrogen atmosphere; the remaining lot is a pristine, prepackaged coal that corresponds to the Herrin (Illinois No. 6) Coal in the Argonne Premium Coal Sample Program. The availability of this coal from both programs contributes to making Illinois No. 6 the most popular selection across the nation.

The availability of well characterized Illinois coals has leveraged a modest investment in the "coal bank" into worldwide research on Illinois coals funded by

other states, governments, and private industry. Most of this research focuses on promoting the use of coal in environmentally acceptable and cost-effective ways.

Coal Analysis Laboratory

Laboratory Services, Chaven, Henry, Brewer This fiscal year, about 840 samples were submitted to the Coal Analysis Laboratory for the ASTM chemical and physical analyses, which required about 4,000 individual determinations. The laboratory has extended its capacity by providing the thermogravimetric (TGA) analytical service to various research projects, in particular the successful scale-up of the high-surface-area hydrated lime process. About 30 samples have also been analyzed by the TGA for pyrolysis, char reactivity, and combustion in support of the clean char project.

Installation of a new micro-elemental analyzer is complete. The instrument analyzes organic and inorganic carbon (carbonate), hydrogen, nitrogen, sulfur, and direct oxygen in coal as well as other solid and liquid materials in milligram-size samples.

The Coal Analysis Laboratory staff are also responsible for recordkeeping, maintenance, and distribution of coal samples from the Illinois Basin Coal Sample Program (IBCSP). Two new samples have been added to the bank, one to replace the depleted lot (IBC 106), and the other to represent the Illinois No. 7 seam. All chemical and physical characterizations have been completed and the results distributed to interested ICCI participants.

At the ICCI request, the laboratory has assumed the responsibility of continuing and updating the bibliography of research performed on Illinois Basin coals. Approximately 620 papers and abstracts associated with research on Illinois Basin coals have been retrieved and categorized for retrieval on the basis of research topics, authors, IBCSP coal samples, and combinations of key words. This bibliographic information is now available, either as hard copy or computer disk, to researchers interested in Illinois coal. A poster on the bibliographic information system was displayed at the annual meeting of ICCI contractors.

Technology Transfer and Information

Characterization of Organic Sulfur in Macerals and Chars, Harvey, Demir, Lowry, Hackley This 2-year project (August 1989 to August 1991) was supported by the Illinois Coal Development Board. The main objective was to describe and evaluate the variation and distribution of organic sulfur within the coal macerals in typical Illinois coals and their charred products. The final report on this project has been submitted to ICCI (ISGS Open File Series OFS 1992-1). Results were presented at the annual meeting of the Society for Organic Petrology in Lexington, Kentucky, and will also be published in *Organic Geochemistry*.

Another paper, "Distribution of Organic Sulfur in Macerals of the Herrin Coal Under Marine and Transitional to Nonmarine Shales," will be presented at the 1992 meeting of the Eastern Section of the American Association of Petroleum Geologists, to be held in Champaign, Illinois, in September. The main conclu-

sion of this work is that whereas the organic sulfur of each maceral type is fairly consistent within separate layers of the seam at the two study sites, each maceral type within the seam under the transitional shale contains less organic sulfur than the same maceral type under the marine shale. The data support the theory that for organic sulfur levels above about 1% in the coal, the sulfur was introduced during a late stage of peat formation when the peat became saturated with sulfur-bearing water during marine transgression.

Distribution and Forms of Chlorine in Illinois Basin Coals, C.-L. Chou The proceedings of the First International Conference on Chlorine in Coal were published in November 1991. The 1989 conference, held in Chicago, was sponsored by the Electric Power Research Institute and ICCI. Dr. Chou helped to organize the conference and contributed a paper on the distribution and forms of chlorine in Illinois Basin coals.

Underclays and Related Paleosols Associated with Coals, Hughes, Demaris, White This chapter on the minerals in Illinois coals and their associated strata was published as part of the book, *Weathering, Soils and Paleosols*.

Mineralogical Analyses of Belle Ayr Coal Samples Harvey, Hughes, Lowry In response to the amendments to the Clean Air Act, more and more power plants in the midwest are blending low sulfur, western coals with high sulfur, Illinois coals.

Fouling and slagging are being encountered. Most western coals contain a different type of mineral matter, which produces a "lignite" ash. Lignite ashes contain more sodium and fewer iron oxides than the typical ash from Illinois coals. These chemicals are thought to be the main cause of the slagging problems.

An opportunity to investigate the mineralogical characteristics of a typical western coal was offered when a mining company provided 11 samples from their preparation plant in Wyoming. The ISGS compared the mineral composition of the western coals with calculated indexes of fouling and slagging propensity. The results suggested that a quartz additive to the western coal blend would likely serve to ameliorate problems of fouling and slagging in Illinois plants when blends of Illinois and western coals are used.

Organic Sulfur Distribution in Float/Sink Fractions of Coal, Harvey, Demir This project was part of the research in characterization of organic sulfur in macerals and chars. The relatively high concentration of organic sulfur found in pyrite-bearing particles of sink fractions of certain samples in the Illinois Basin Coal Sample Program was discussed at the Coal Advisory Committee at its May 1992 meeting.

The Rank of Illinois Coals, Harvey An accurate classification of coals by rank according to the American Society for Testing and Materials (ASTM) is important to many coal producers, utilities, and taxing agencies in Illinois. Dr. Harvey serves as chairman of

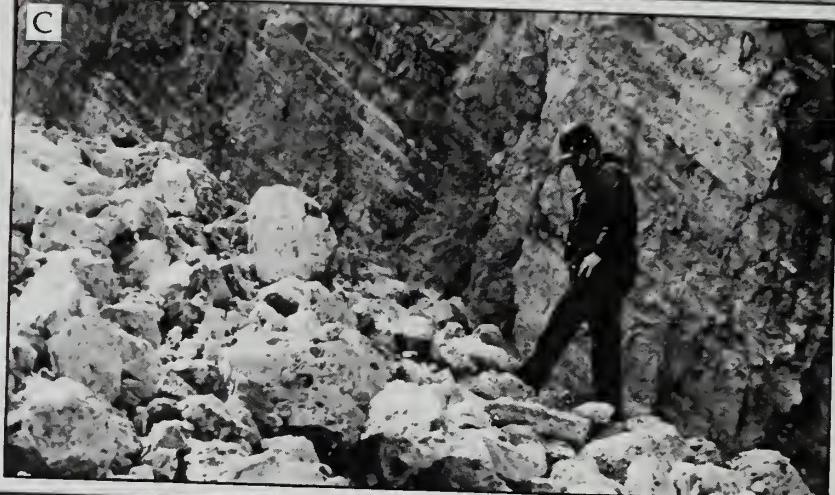
(A) Petroleum engineers take permeability measures of the Cypress Sandstone outcrop along Interstate 57 near Anna, Illinois. (B) Geologist D. Scott Beatty prepares thin sections of sandstone for petrographic analysis. (C) Donald G. Mikulic, industrial mineral geologist, inspects a blast rock in Thornton Quarry. (D) Emmanuel Udegbunam, petroleum engineer, and Hannes Leetaru, petroleum geologist, work on a three-dimensional computer model for the Improved and Enhanced Oil Recovery Program. (E) Philip J. DeMaris, geologist, slices a coal ball to examine plant material.



B



A



C



D



E

the ASTM Subcommittee on Classification of Coals. It is mainly through the ASTM that the Illinois coal industry keeps informed of international developments on rank classification—developments that may impact the exporting potential of Illinois coal.

ISGS input on Illinois coals was used by the delegate from USDOE to persuade the Coal Committee for the United Nations Economic Commission of Europe (UNECE) to agree to suggested changes on behalf of the Illinois coal industry. At present, the UNECE classifies Illinois coals within the Bituminous Rank category for purposes of exportation to European markets. Documents have been submitted to the USDOE delegate to the UNECE to cover the procedures by which coal is sampled in Illinois and to help ensure that ISGS sampling methods will conform to those adopted as a UNECE standard in the future.

General Information on Illinois Coal, Damberger, Coal Section staff Many kinds of requests for information on Illinois coal are handled by the staff of the Coal Section. For instance, a report in the *Fairview Heights Journal* on the potential of mine subsidence in the Fairview Heights area of St. Clair County prompted more than 150 requests for information by people in the area. A letter to the editor of the paper helped correct misinformation contained in the article.

Typical requests are for information on coal resources under farmland, the extent of mining under a parcel of land or a construction site, or the incidence of mine subsidence above a given mine or within an area. Engineers often inquire about the presence of past or current mines, mining problems, and the potential for subsidence. Many questions can be answered directly on the phone; others require research into our extensive database. In many cases, the information has been published in reports and maps on coal resources, structure, and mines.

Common questions also relate to the quality of coal in specific areas, or in Illinois in general. Several companies showing interest in the acquisition of coal reserves were provided with information to help focus their exploration and/or acquisition efforts.

Particle-Size Enlargement of Fine Coal or Char Using Lignocellulosic Residue, Ehrlinger, Chow (UI-UC); Strickland (TVA) The paper, "Use of Wood Lignocellulosic Wastes as an Adhesive for Desulfurized Fine-Sized Solid Fuels," was given by Ehrlinger in Seattle, Washington, in November 1991. The final report is expected to be out during the next report period.

OIL AND GAS

Domestic oil production continues to decline. In Illinois, production for 1990 was 19,954,000 barrels of oil, and for 1991, 19,069,000 barrels of oil. During 1991, 1,400 wells were plugged in Illinois. Joining the effort to revive the depressed Illinois oil industry, the ISGS committed its research and service in oil and gas resources to aiding independent oil producers. The objective is to recover higher percentages of oil from

existing fields. The program also develops incentives to encourage exploration, promotes wise development of the state's oil and gas resources, and provides complete and timely information to the oil industry. The information allows a more accurate definition of the subsurface and enables operators to visualize, locate, and cost-effectively develop the resource.

Results from work completed in the Improved and Enhanced Oil Recovery Program, jointly supported by the Illinois Department of Energy and Natural Resources (ENR) and the U.S. Department of Energy (USDOE), indicate that important oil resources may exist in known Illinois reservoirs. The ISGS program is demonstrating to the USDOE and industry that an understanding of reservoir architecture and heterogeneity will effectively help in the design and utilization of economic and technologically advanced practices to increase production.

The Illinois program was selected by the USDOE's technical management to be presented to the Assistant Secretary for Fossil Energy in Washington, DC, as a programmatic example of the benefits of state and federal cooperation. The presentation highlighted advanced techniques for reservoir characterization and management to improve oil recovery in Illinois.

Oil and Gas Program for Illinois

Program planning and strategy for the 1990s focuses on recovering higher percentages of oil from Illinois' petroleum-producing reservoirs. Wells are abandoned annually in Illinois and access to unrecovered oil is lost. Economic recovery of unrecovered mobile oil presupposes the use of existing wells. Increased understanding of the nature of the reservoirs requires advanced geological, geophysical and engineering reservoir characterization to define and model reservoir characteristics that inhibit recovery. Representative fields are being screened for unrecovered oil.

The oil and gas research program has several significant goals:

- screen selected Illinois reservoirs to define the state's remaining, unrecovered mobile oil (currently estimated at 1.4 billion barrels);
- transfer results of research not normally available to the Illinois independent oil producers;
- demonstrate the effect of various technologies on Illinois reservoirs through advanced imaging and predictive modeling;
- identify, demonstrate, and test technology that will enhance production from mature fields;
- prove that future reserves in Illinois can come from extensions to and intensive, directed development of existing fields through geologically targeted, infill drilling and improved waterflood design;
- encourage renewed hydrocarbon exploration in the Illinois Basin.

The ISGS Oil and Gas Program continues to aid the petroleum industry in the exploration and development of Illinois' resources by providing comprehensive data collection, mapping, subsurface stratigraphic analysis of possible new petroleum targets, and new

techniques for exploiting existing fields and plays. Oil and gas data are made available to the public via (1) a report on the petroleum industry in Illinois, (2) a monthly drilling report, (3) Oil and Gas Development Maps, (4) Oil and Gas Pay Maps (showing the geographical area underlain by oil production from individual rock layers), (5) maps showing the subsurface depths of selected strata, (6) special publications, and (7) the Geological Records Unit, which contains data from more than 342,000 wells, including data from more than 140,000 oil and gas tests.

Oil and Gas Statistics

Annual Statistics and Records, Huff, Liu Geological records, including well logs, are submitted to the ISGS from wells drilled each year by industry in accordance with state laws and regulations.

Holes reported in 1990, as compared to 1991

	1990	1991
Oil and gas tests		
New holes	1201	882
Old dry holes drilled deeper, reentered or reworked, and completed as oil wells	NP	73
Service wells		
New holes	160	76
Old holes reentered or reworked or converted	NP	53
Structure tests	1	0

NP = none processed

The 882 new holes in 1990 included 452 oil wells, 22 gas wells, and 408 dry holes. In 1991, Illinois ranked fifteenth in the United States in oil production; annual production (fig. 2) fell to 19,069,000 barrels, 4.4% less than in 1990 and its lowest total in more than 50 years. Discoveries reported included four new pay zones in existing fields, and six extensions to fields.

Illinois production in 1990, as compared to 1989

	1990 MB/month	1991 MB/month	% change from 1990
January	1,849	1,549	-16.2
February	1,578	1,430	-9.3
March	1,737	1,662	-4.3
April	1,595	1,378	-13.6
May	1,628	1,701	+4.5
June	1,569	1,547	-1.4
July	1,761	1,751	-0.5
August	1,760	1,688	-4.0
September	1,623	1,589	-2.1
October	1,711	1,678	-1.9
November	1,682	1,512	-10.1
December	1,461	1,583	+8.3

MB = 1000 barrels

Improved Oil Recovery Methods and Concepts

The major research effort, Improved and Enhanced Oil Recovery Through Reservoir Characterization, jointly supported by ENR and USDOE, is in its final year.

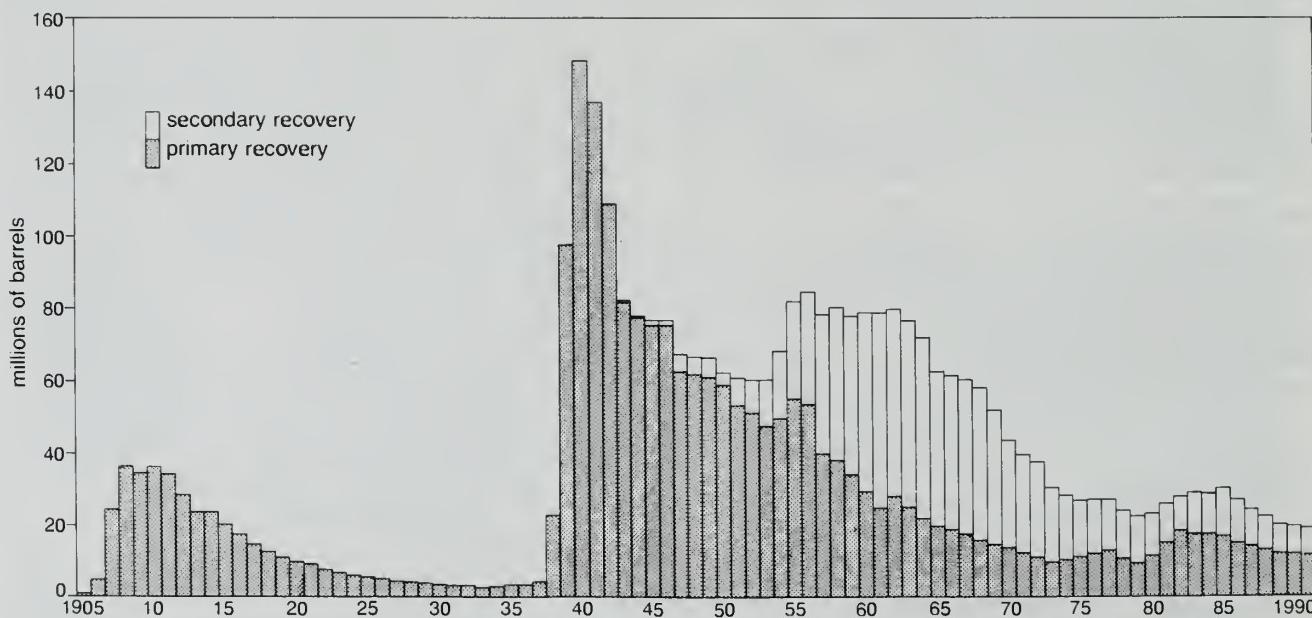


Figure 2. Yearly oil production in Illinois.

This \$4.9 million, 4-year effort has been aimed at providing information to maximize hydrocarbon recovery: estimates are that 1.5 billion barrels of unrecovered mobile oil (UMO) remain in Illinois reservoirs after normal production. Using advanced methods, scientists are evaluating remaining reserves in Illinois oil fields. The results are promising; for example, King Field may contain as much as 1 to 2 million barrels of UMO.

The transfer of technology to industry and the public is a significant part of the program. The project provides information on hydrocarbon resources, reservoir characterization, and methods to improve mobile hydrocarbon extraction. During the year, information was distributed through 25 presentations (workshops, symposiums, talks, displays) and publications. The field and project reports highlight progress on the USDOE/ENR program, which focuses on the Cypress and Aux Vases sandstones—two of Illinois' most prolific oil-bearing strata.

Reservoir Studies

Cypress Sandstone

Reservoir Location	
Field	County
Bartelso*	Clinton
Lawrence	Lawrence
Mattoon	Coles
Parkersburg	Richland, Edwards
Richview	Washington
Tamaroa	Perry
Xenia East	Clay

Aux Vases Sandstone

Reservoir Location	
Field	County
Boyd	Jefferson
Dale Consolidated	Hamilton
Energy	Williamson
King**	Jefferson
Mattoon	Coles
Oakdale/Markham City N	Jefferson
Stewardson	Shelby
Zeigler	Franklin

* in press

** published during the year as IP 135

Bartelso Field, Whitaker, Finley The report on reservoir heterogeneity and the potential for improved recovery from the Cypress Formation at Bartelso (ISGS Illinois Petroleum 137) was sent to press in May 1991. A method for subdividing the Cypress Formation to enhance economic management of the reservoir is proposed in this report. The geologic model can be used to improve understanding of Cypress deposition and resulting reservoir heterogeneity in this and similar reservoirs.

Boyd Field, Leetaru The lenticular nature of the reservoir sandstone in this field has resulted in lateral and vertical compartmentalization, which has allowed large areas of the Aux Vases reservoir at Boyd Field to remain unswept by previous waterflood projects. Production from the Aux Vases has been commingled with the Yankeetown Formation. The higher reservoir pressure in the Yankeetown inhibits the flow of oil from the Aux Vases reservoir and thereby lowers recovery efficiency in the Aux Vases. Technology is available to isolate producing zones in a well and implementation of that technology could increase recovery from the Aux Vases in this field.

Dale Consolidated Field (Cantrell, Cantrell South, McCreery, and McCullum Units), Beatty, Fagan Three sandstone bars in the Aux Vases Formation at southwest Dale Consolidated Field form structurally modified stratigraphic traps. These bars are "shingled" and may be separated by shale beds only 2 feet thick. Although heterogeneities exist at all scales, permeability cross sections show two distinctive flow units that are present in all three bar intervals: an upper highly permeable oil saturated unit, and a lower less permeable but still oil-saturated unit. Petrographic analyses of 40 core samples from the study area reveal that a relatively high amount of calcite cement in the lower units causes the permeability variation.

A Stratigraphic Geocellular Model (Stratamodel) and an engineering simulation were created for two of the five waterflood divisions in the field, the McCreery and McCullum Units. In the study area, the maximum regional stress axis (σ_1) trends roughly east-west. In McCreery and McCullum Units, hydraulic fracturing techniques created fracture networks oriented subparallel to σ_1 . These networks connect east-west offset wells and lead to inefficient sweeping of mobile oil in interwell areas. The final report is near completion.

Energy Field, Huff This investigation showed that depositional environments during a regressive-transgressive cycle were the major cause of reservoir heterogeneity in the field; four distinct reservoirs within the Aux Vases Formation have been documented. Secondary recovery efforts in the field have only partially swept the reservoirs; problems are due to injection well geometry and incomplete understanding of reservoir geometry. An estimated 531,000 barrels of unrecovered mobile oil remains to be produced using current reservoir management techniques. The total recoverable oil may be increased with a waterflood that is positioned utilizing the new geologic data.

A manuscript has been completed and peer reviewed. Another manuscript by Udegbunam and Huff (in preparation) integrates geology and engineering aspects to model the field and determine optimal recovery scenarios.

King Field, Leetaru A three-dimensional model of the geology of King Field was used to decipher the depositional history of the Aux Vases Formation. The model was generated using SGM® software by Stratamodel®

on a Silicon Graphics® workstation. Fieldwide, the vertical and lateral variations in lithofacies are best visualized using three-dimensional modeling. The geometry of the Aux Vases reservoir and its relationship to other lithofacies can be better understood by using the model to "traverse up" layer by layer through the formation. The areal distribution of the best reservoir rocks can be identified by using the model, so that geologists and engineers can design cost-effective ways to recover additional reserves from King Field.

Lawrence Field, Grube, Cole, Whitaker The Lawrence Field pilot study is in the mapping and petrographic analysis phase. Core descriptions have been completed; engineering analysis and simulation has been initiated.

This study is centrally located along the west flank of an anticline that forms the northern structure of the multiple-structured field. Reservoirs form in sandstones of the middle Cypress. No upper Cypress sandstones are present. The middle Cypress sandstone is approximately 50 feet thick and composed of stacked sheet sands that are commonly 10 feet thick.

Mattoon Field, McGee This field, located in southwest Coles County, Illinois, is a 6,680-acre anticlinal trap that was discovered in February 1939. Less than half of the total 667 completions are active today. Principal production is from the Mississippian-age Cypress, Aux Vases, and Rosiclare sands. More recently, completions have been made from several Lower Mississippian and Devonian-age intervals. Cumulative production from Mattoon Field, as of October 1989, was 21,595,417 barrels of oil with a daily field production of 298 barrels of oil. These figures do not include production from Mattoon North or Mattoon South.

The initial phase of this project focused on intraformational relationships. The project now is focused on the interformational delineation of individual sands within the Cypress Formation. The Mattoon Field database required quality control corrections and updating. Extreme heterogeneity within the Cypress Formation has required use of 633 individual well logs, 41 stratigraphic cross sections, and individual structural, isopach, and facies maps of four intraformational Cypress intervals.

Oakdale and Markham City North Fields, Crockett Oakdale and Markham City North Fields in Jefferson and Wayne Counties are closely associated, combination stratigraphic and structural traps in the Aux Vases Formation. Deposition was in a shallow water, mixed carbonate and siliciclastic environment. Oakdale's production is primarily from the Aux Vases, with minor Ste. Genevieve production; whereas Markham City North produces oil predominantly from Ste. Genevieve oolitic carbonate reservoirs with minor Aux Vases production.

Most wells at Markham City North were drilled in the 1940s prior to the use of fracturing, a commonly applied method of stimulating production in the Aux Vases. It was not until the 1950s, when the method was routinely practiced, that the Aux Vases became an

important, prolific exploration target in Illinois. The Aux Vases, particularly the wells drilled prior to the advent of fracture technology at Markham City North, are being examined for potential as a bypassed pay zone. The oil production statistical database is nearly complete. The next steps are to conduct engineering evaluation of the fields and begin reservoir simulation modeling within the established geologic framework.

Parkersburg Area, Seyler Cypress reservoirs in the Lower, Middle, and Upper Cypress sandstones have been identified in an area 30 miles square in the vicinity of the Parkersburg Field in Richland and Edwards Counties, Illinois. There are 504 wells in the area; 106 produce from the Cypress Sandstone. The middle Cypress has produced the most oil in this area; the Lower Cypress is the next most productive; a minor amount of oil comes from the Upper Cypress. Sea level fluctuations, changes in sediment influx, and marine processes have played a controlling role in the formation of reservoirs in these Cypress sandstones. The lower Cypress may have been deposited in a lower delta plain environment; reservoirs may occur in delta mouth bars, lower distributary channel fills, and crevasse splays. Middle Cypress sandstones are generally cleaner, and where oil-productive, thicker than other Cypress reservoirs in the area. This is a result of being reworked in a shallow marine environment.

Richview Field, Grube This study is nearly complete; volumetric calculations, final map interpretations, and initial manuscript preparations are in progress.

The northeast-southwest-trending field appears to be largely stratigraphically controlled. The sandstones facies rapidly change to shale away from the field. Structurally, the field lies in a saddle between Irvington Field to the north and Ashley Field to the south. Richview Field lies immediately west of and on the uplifted limb of the Du Quoin monocline.

Richview Field has produced more than 3.2 million barrels of Cypress oil from 86 wells on 800 acres. Although some production is attributed to a stray, upper sandstone that immediately underlies the Barlow Limestone, most of the oil has been produced from the upper 20 feet or less of a sandstone, the top of which is 10 to 30 feet below the base of the stray sand horizon. This sandstone varies in thickness from 20 to 50 feet and displays a very clean, blocky SP log character. Increases in thickness occur as incremental, blocky sands, 10 to 20 feet thick, indicating a stacking of genetic depositional units. Logs indicate that thin, laterally traceable shales separate these sand units.

Stewardson Field Study, Rice, Cole, Whitaker The report, *Reservoir Characterization of the Mississippian Aux Vases Formation at Stewardson Field in Shelby County, Illinois*, was submitted for publication in May 1992. The study indicates that sandstones in the Aux Vases Formation at Stewardson Field exhibit less porosity and permeability than Aux Vases reservoirs studied by the ISGS from the more southern portion of the Illinois Basin. However, this relatively poor reservoir quality

has not translated to equally poor recovery efficiency. This is partly because of the environment of deposition and the presence of a small paleostructure at this locality during deposition of the Aux Vases. Remaining recoverable reserves are approximately 100,000 barrels of oil, given present extraction methods.

Storms Consolidated Field, Leetaru, Rice More than 400 electric logs have been used to generate cross sections, isopach, and structural maps. Currently the degree of compartmentalization in the Cypress and Aux Vases reservoirs is being evaluated.

Tamaroa Field, Grube An important conclusion of the Tamaroa Field study is that both reservoir compartmentalization and pressure maintenance control cumulative production and ultimate recovery efficiency. Maximum production in this field can be obtained by draining and pressure maintaining separate correlative sandstones from a vertically stacked, multilateral, marine bar setting. Both marginal and very successful production programs are apparent in the multiple oil reservoirs of Tamaroa and Tamaroa South fields. Recovery of 40,000 to 60,000 barrels of oil per well from 10-acre spacing and less than 10 feet of reservoir thickness is typical where pressure is maintained in distinct, correlative sandstone bodies. Recovery efficiency for the effectively managed reservoirs is 43%.

The final report on the Tamaroa Field study is scheduled for publication in the fall of 1992.

Xenia East Field, Xu Work has been completed for the Cypress pool project; the manuscript is in peer review. The report consists of four parts: reservoir and trap characteristics, classification and identification of play, production characteristics, and development and production strategy.

Regional Studies

Geochemistry of Formation Fluids and Predictive Geochemistry, Demir, Black, Oltz The purpose of this project is to characterize and model the chemistries of reservoir fluids to predict changes in reservoir properties (composition, porosity, permeability) in response to paleochemical reactions or the injection of enhanced oil recovery fluids. Seventeen brine and 14 oil samples were collected from the Aux Vases and Cypress formations and analyzed for various geochemical parameters. Geochemical data from 296 additional, historical brine samples from the same formations were obtained from a USDOE collection, processed, and added to the database. The areal distributions of the measured resistivity values were mapped. The geochemical data and mineralogical data are being used as input for a computer modeling code for predictive geochemistry.

Outcrop Study of the Cypress Formations, Cole, Haggerty The outcrop work on four parallel roadcuts along Interstate 57 in Union County was completed in March 1992. Twenty additional sections were measured, logged with a hand-held gamma-ray spectrometer, and measured with the field minipermeameter.

Four photomosaics of the roadcuts were constructed, and depositional facies traced out on a mylar overlay; 180 paleocurrent measurements were also plotted on the overlay. The data document details of reservoir heterogeneity that can be extrapolated to buried reservoirs, and thus aid operators in visualizing heterogeneity at depth. Analogs such as these outcrops will help operators understand the complexity of reservoirs and lead to improved recovery of oil.

Field Investigations of the Aux Vases and Cypress Formations, Cole Two manuscripts have been submitted for review: (1) a historical and stratigraphic analysis of the Mississippian Aux Vases Formation, and (2) a petrographic investigation of the Aux Vases. Additional manuscripts in preparation include a synthesis of Cypress Formation exposures and a comparison of outcrop and subsurface examples in the Aux Vases Formation.

Pressure-Volume-Temperature (PVT) Studies of Illinois Reservoir Crude Oils, Sim This PVT project has been completed and a report is in preparation. Several commonly used PVT correlations were evaluated for their accuracy in calculating PVT properties of Illinois crude oils. Improved correlations for Illinois reservoir crude oils have been derived using experimental results from the ISGS petroleum engineering laboratory and results from phase behavior simulation.

Regional Petrographic Study for the Aux Vases Sandstone, Seyler, Beatty A regional paleochemical (diagenetic) sequence for reservoir development has been generated for the Aux Vases Sandstone in Zeigler (Franklin County), Energy (Williamson County), Dale Consolidated (Hamilton County), Oakdale (Jefferson County), and Boyd Fields (Jefferson County). This study includes synthesis of thin section, SEM/EDX, and XRD analyses with interpretations of similarities in depositional processes, reservoir geometries, wireline log responses of reservoir rocks, reservoir behavior, and reservoir management practices. Results indicate that modifications during and after deposition are responsible for development of contrasting reservoir rocks in the Aux Vases over the study area. Variations that occur within and between fields must be incorporated into the design of drilling, completion, and recovery treatments that maximize recovery efficiency.

Regional Petrographic Study for the Cypress Sandstone, Seyler, Beatty A regional paleochemical (petrographic) synthesis for development of reservoir quality sandstones has been generated for the Cypress Sandstone in Parkersburg (Edwards and Richland Counties), Mattoon (Coles County), Tamaroa (Perry County), Richview (Washington County), Bartelso (Clinton County), and Xenia East (Clay County). This study synthesizes thin section, SEM/EDX, and XRD analyses with interpretations of depositional environments to determine the role that depositional and post depositional processes play in formation of reservoir quality sandstones. Similarities in reservoir characteristics will

guide the design of drilling, completion, and recovery techniques that lead to efficient recovery of petroleum from Illinois reservoirs. The results of this study will be published in the paper, "The Role of Diagenesis on Reservoir-Fluid Interactions in the Aux Vases and Cypress Sandstones," which is in review.

Petrographic Atlas of Aux Vases and Cypress Sandstones, Seyler An atlas illustrating, cataloging, and describing samples examined by SEM/EDX, cathodoluminescence, and light microscopy is being generated in conjunction with the IOR/EOR DOE project. To date, six volumes encompassing reservoir samples from the Cypress Sandstone at Bartelso, Xenia East, Tamaroa, Richview, Mattoon, and Parkersburg Fields as well as samples from the Aux Vases Sandstone at Zeigler, Boyd, Stewardson, King, Dale Consolidated, Energy, and Oakdale Fields have been completed.

Mineralogy of Chlorites, Moore, Hughes (ISGS); Reynolds (Dartmouth College); Lahan (Conoco Inc.) Clay minerals such as chlorite affect the porosity and permeability of petroleum reservoir rocks. Their reactions to fluids commonly introduced into reservoirs during drilling, stimulation, and production can cause significant decreases in permeability and oil production. To quantify the impact of these reactions, investigators are examining the chemical and physical constitution of clay minerals. Small amounts of serpentine-like (soapstone) mineral layering in the chlorites from Aux Vases and Cypress sandstone oil reservoirs have been identified. Findings from these studies are being correlated with the fluid-flow properties of the rocks.

Samples of chlorite donated from several of the major oil fields throughout the world have shown that the distribution of interlayered chlorite is widespread. This universality suggests that the formation of these chlorites is a result of thermal and chemical changes that may also have accompanied the generation and migration of hydrocarbons. Three hundred fifty more samples have been analyzed. Correlations have been made between the characteristics of each of the reservoirs and the associated variety of chlorite.

Integrated Geologic/Engineering Field Studies Seismic Study, King Field, Jefferson County, Illinois, Whitaker, Oltz, Fagan, Heigold Ten and one-half miles of high resolution, high fold, conventional reflection seismic data was acquired from King Field in Jefferson County, Illinois. The data were obtained to demonstrate that a well designed seismic program would detect both horizontal and vertical reservoir heterogeneity.

Throughout the operation, an interactive approach was taken because of the lack of empirical data. Field tests, data acquisition, and data processing were all monitored to accommodate existing geological data. Preliminary interpretation of the records has been integrated with in-field well logs and vertical seismic profile data. Preliminary data examination suggests that the thin (10 to 12 feet) Aux Vases formation can be identified and that the variation in seismic response to

the Aux Vases may indicate stratigraphic variation has some control on production.

Clay Mineralogy of Reservoirs, Moore, Hughes, Beaty Clastic and carbonate samples from Cypress and Aux Vases oil fields, selected for clay and bulk mineral analysis, were analyzed. More than 300 samples were analyzed in the last year in support of the oil and gas field studies to establish the impact of mineral content on reservoir behavior. Significant variation has been observed for the bulk content of minerals, the types of clay minerals, and the correlation between clay mineral type and bulk mineral content. A new method of mineralogical analysis was developed to permit more accurate analysis of previously analyzed sample sets.

Dale Consolidated Field—McCreery and McCullum Units, Udegbunam, Beaty, Fagan An integrated geologic and engineering study of the McCreery and McCullum Units in the Dale Consolidated Field has been completed. Its scope included data gathering, analyses, interpretations, and integration for input into a reservoir simulator for evaluation of reservoir behavior and prediction of future reservoir performance.

The pressure-volume-temperature (PVT) properties of the oil and gas from these reservoirs were analyzed in the ISGS PVT laboratory. Petrographic, SEM, and XRD work identified mineral contents. Isopach maps, formation tops, and porosity and permeability values were used as input into the reservoir simulator. The operator provided information on the field production history that was also input into the simulator.

The simulator was used to model the historical depletion of the units. Also compared were the potential effects of various options for placement of water injection wells with the effects of hydraulic fracturing on waterflood oil recoveries. Simulated predictions that hydraulic fracturing in these reservoirs would adversely affect waterflooding are now being confirmed by reports from actual waterflood operations.

Simulation Modeling of Energy Field, Udegbunam, Huff Simulation modeling of Energy Field has been completed and a manuscript is being prepared. Various models of the field were simulated to determine factors affecting oil recovery from the reservoirs. A two-dimensional model and a single-well radial model were used to study the effects of early water injection for pressure maintenance and wellbore formation damage on productivity of Energy Field, respectively. The effectiveness of the historical water injection programs was also studied using a three-dimensional, full-field reservoir model. Finally, an optimal incremental oil recovery strategy based on simulated results was suggested. The simulated results suggest that strategic location of infill wells along with properly designed waterflood programs will enhance recovery of bypassed oil from both units of the Energy Field.

Experimental Investigations of Formation Damage in Aux Vases Reservoir Rocks, Udegbunam, Seyler, Haggerty This report is nearly complete and will show

experimental results obtained when Aux Vases rock samples are flooded with mud cleanout acid (15% HCl with additives) and injection water of various salinities. Data from thin sections, SEM/EDX, and XRD analyses of Aux Vases sandstones from various oil fields were used in this work. Permeability changes resulting from injection of fluids are explained with regard to rock mineralogical changes and can be used to establish the least damaging fluids for reservoir treatment in Aux Vases formation.

Zeigler Field, Seyler, Sim An integrated engineering and geologic study of the Aux Vases reservoir at Zeigler field shows that a series of shingled and overlapping shallow, marine sandbars deposited in a tidally dominated environment have limited lateral and horizontal dimensions that exert control on production. A generally efficient and economic program of development has led to recovery efficiencies of 50% or better for the field—far exceeding industry averages. Reservoir simulation and history matching show that water flooding has been a highly effective secondary recovery method. Pressure maintenance has been a key factor in the reservoir management program at Zeigler; pressure data are one of the most important measures of reservoir performance and are an essential element in the design of an efficient and effective recovery program. Pressure differentials in the field have highlighted separate lenses in the field and a major separation between the eastern and western portions of the field.

Reservoir Simulation Study of Zeigler Field, Sim, Seyler An integrated geological modeling and reservoir engineering simulation study on the Zeigler Field in Franklin County is near completion and the report is in preparation. A reservoir model has been constructed to simulate oil and water production and pressure history of the 30 productive wells over the past 30 years.

This model estimates that the original oil in place in a portion of the field (i.e. on the Plumfield lease) is 4.5 MMSTB; and the overall post waterflood recovery was 43%. Simulation results showed that additional oil from the eastern portion of the Plumfield lease could have been recovered if pressure maintenance was started earlier. The distribution of unrecovered mobile oil was identified for possible future implementation of improved oil recovery technology.

New Exploration Methods and Concepts

Geologic Maps of the Lower Pope Group in Jefferson County Area, Whitaker, Leetaru A pilot study is underway for regional mapping of eight formations in the Lower Pope Group. This project will lead to a better understanding of the geometry of these formations and help in developing hydrocarbon exploration and development.

Sequence Stratigraphy of the Lower Pope Group, Whitaker This project, coupled with regional mapping, will help to determine the interrelationships of the various units that make up the Lower Pope Group. Se-

quence stratigraphy, which has not been applied to the Illinois Basin previously, will be used to determine an accurate and detailed picture of the depositional history of the Lower Pope Group. Results from this study should influence geologic play conceptualization and open new frontiers in the exploration for hydrocarbons in this horizon.

Tar Springs Sandstone Hydrocarbon Reservoir in Sailor Springs Consolidated Field, Howard An assessment of geological factors that led to the occurrence of commercial hydrocarbon accumulations in the Tar Springs sandstone reservoirs within four-township area of Sailor Springs Consolidated Field in southeastern Clay County has concluded. The database included more than 2,000 electric logs, plus selected cores and cuttings. Striking evidence of the development of an anastomosing network of thick distributary sandstone bodies within the lower Tar Springs was not unexpected, nor was the discovery that the upper Tar Springs pay zone comprised relatively thin, shale-bounded, transgressive bar sandstones draped across compaction anticlines. What was surprising was the strong indication of a heretofore unknown linear fault trend that appears to align with recently discovered reverse-faulting at Johnsonville Consolidated Field about 15 miles to the southwest.

Fracturing of the underlying dense Glen Dean Limestone along this trend could have allowed upward migration of hydrocarbons into Tar Springs reservoirs at Sailor Springs. Indeed, faulting of the Glen Dean must have been the key to the emplacement of a significant Tar Springs oil accumulation more than 40 miles from the main Tar Springs producing area. An important play concept thus emerges: to consider the exploration potential for upper Chesterian sandstone reservoirs along faults.

Hydrocarbon Generation and Migration

Differentiation of Ordovician Oils, Salmon, Risatti, Hatch (USGS) Two types of oils that can be differentiated on the basis of saturated hydrocarbon biomarkers may have been produced in the Maquoketa Formation. The oils were further differentiated through analysis of 21 oil samples from the Illinois Basin. The research has promoted a hypothesis of postdepositional maturation of these oils. The results and interpretation of data will be reported in a journal article.

Maturity Indicators of Illinois Basin Oils, Salmon, Kruse (SIU-C) Investigations into parameters that indicate the maturity of Illinois Basin oils from different horizons are being conducted. Saturated and aromatic compounds of oils are being compared and contrasted to propose universal thermal maturation indices within these oils. The study involves analysis of approximately 135 Illinois Basin oils that were selected to provide the widest areal range and the maximum coverage of different oil types. The oils will be separated into four fractions by liquid chromatography, then analyzed by gas chromatography. The samples are now being fractionated and analyzed.

Cross Basin Correlation of Crude Oils, Salmon, Risatti (ISGS); Meyers (University of Michigan); Curiale (Unocal Corp.); Hatch (USGS) Investigations into the biomarker and compound specific isotope analysis of Ordovician-age oils from three separate basins are being conducted. The purpose of this research is to correlate the oils across three different basins (Illinois, Michigan, and Forrest City), by using a suite of organic biomarkers. Gas chromatography mass spectrometry analysis will be conducted at the ISGS, and interpretation of the data will be made in conjunction with coinvestigators at the ISGS and other locations.

Three cores were selected from Illinois: one from Perry County, one from White County, and one from Schuyler County. Twenty-five samples from the Perry County core were extracted and the oils are now being fractionated; 310 samples from the White County core are being prepared for extraction of oils. The Schuyler County core is now being sampled.

Maquoketa Formation Cross-Basin Correlation, Salmon (ISGS); Kruse (SIU-C) This project involves the sampling of five Maquoketa Formation cores from across Illinois in an attempt to correlate the organic geochemical signatures with distinct organic facies. Selection of the cores was based upon the existence of three members: Scales shale, Ft. Atkinson limestone, and Brainard shale. They represent environments of deposition ranging from restricted basin marine to deep water marine. Four of the cores have been sampled (about 400 samples); and extraction and analyses of the samples are in progress.

Oil-Oil Correlations in the Illinois Basin by Compound-Specific Isotopic Analysis, Risatti, Salmon (ISGS); Bakel (Argonne National Laboratory) Examination of a suite of Illinois Basin oils that had previously been grouped into three family types by using conventional geochemical techniques was accomplished via compound-specific isotopic analysis. Plots of $\delta^{13}\text{C}$ versus n-alkane (C_{12} - C_{35}) were found to be distinctive for each of the oils and for the oil type. Most pronounced differences were found in two families of Ordovician oils thought to have been sourced from different organic matter assemblages. The $\delta^{13}\text{C}$ of the C_{18} - C_{24} n-alkane fraction ranged from -33.1 to -34.4 for type II oils and -29.7 to -32.9 for type I oils. In addition, the $\delta^{13}\text{C}$ n-alkane of the C_{12} - C_{17} fraction in the Ordovician oils examined appears to correlate with other maturation parameters. These data were presented at the American Chemistry Society annual meeting in San Francisco during April 1992.

Geochemistry of Natural Gas, Riley, Liu, Coleman Natural gas samples collected as part of ISGS oil, gas, and water well testing programs, along with samples submitted by individuals and industry, are analyzed to determine their chemical and isotopic compositions. The information adds to our basic database on the geochemistry of natural gas in Illinois and is frequently used to distinguish gases from different sources and to help solve both production and environmental prob-

lems. During the reporting period, eight natural gas samples were analyzed.

Oil and Gas Database Management

Computer-Generated Oil and Gas Development Maps, Frankie, Olt, Sroka The development of a computer-generated series of maps to replace the older ISGS series of hand-drawn Oil and Gas Development Maps continued. Twenty-four of the 83 maps are now produced via computer; they are available at the same scale as the older series. Customized maps can also be generated at various scales and for specific interests within the areas completed to date. The maps are available in color or diazo reproduction. For this project, more than 25,000 well records were updated in the ISGS computer database.

Maps Currently Available

Cave in Rock (no. 9)	Rosiclare (no. 10)
New Burnside (no. 11)	Goreville (no. 12)
Alto Pass (no. 13)	Murphysboro (no. 16)
Thompsonville (no. 18)	McLeansboro (no. 22)
Benton (no. 23)	Pinckneyville (no. 25)
Nashville (no. 32)	Noble (no. 40)
Clay City (no. 41)	Effingham (no. 59)
Shelbyville (no. 71)	Mattoon (no. 72)

VAX 3800, VAX 3200, VAX 3100, VAX 4000, and VAX 5000, Yeko, Lecouris Fourteen new people were given access to the database VAX 3800; four new people were given access to the VAX 3200. The VAX operating system was upgraded to v 5.4-2 on both systems. A VAX 5000 and VAX 4000 were acquired for running ZMAP PLUS software and developing software.

NRIF Well Data Sales, Lecouris Sale of computerized well data continued under the Natural Resources Information Fund agreement. This year, 37 customized, computerized data retrievals were completed to provide oil and gas and water data for industry. This represents a significant increase in demand.

Well Database Management System, Yeko, Lecouris The QuESToR program of about 18,000 lines was developed. Based on a "point and click" windowing scheme (X-Windows), this program was designed to allow individuals who are not computer experts access to the ISGS well databases. The program will allow the public to view basic well data and to determine additional data that are filed as hard copy.

Negotiations were begun with a Chicago-based consulting firm, The Ultimate Software Consultants (TUSC), to bring the QuESToR software to the general market place. A preliminary agreement was reached and joint software evaluation and development was begun. A commercial release date of September 15, 1992, is scheduled to coincide with the International Oracle Users Group Conference in San Francisco.

Final transfer of the remaining PRIME databases to the database VAX was completed. The collection of

programs that enable the ISGS Geological Records Unit to track and report on oil and gas wells was completed. Testing and evaluation was performed and numerous enhancements made. The system was operational before the shutdown of the Prime on July 1, 1992.

The CONQuEST retrieval system was enhanced to allow network access to the shared database as the fragmented individual databases were centralized on the database VAX.

Database of Illinois Basin Oil Sample Properties, Salmon A database is being developed for basic chemical, physical, and logistic information about crude oils from the basin. The framework of the database has been established; it now contains logistic information for 1,934 samples. Some physical data have also been entered.

Technology Transfer and Information Services

Technology Transfer for Improved and Enhanced Oil Recovery Project The poster, "Oil and Gas Potential in the Paducah Quadrangle," was presented at the USGS and Illinois Basin Consortium Public Meeting in St. Louis, Missouri, in January 1992. About 170 participants from industry, the cooperating geological surveys, the public, and the media were present.

At the American Institute of Professional Geologists Symposium, "Past, Present, and Future 100 Years of Petroleum in the Illinois Basin," two papers were presented by ISGS staff: "Present and Future Hydrocarbon Exploration in the Illinois Improved Oil Recovery Project," and "The Potential for Future Hydrocarbon Exploration in the Illinois Basin."

Presentation to James Randolph At the invitation of USDOE, four members of the ISGS Improved and Enhanced Oil Recovery Project team traveled to Washington, DC, in March 1992 to meet with James Randolph, the Assistant Secretary for Fossil Energy. They outlined the project design and summarized results to date. Several USDOE staff managers also attended the presentation.

The Illinois program was singled out as one of the USDOE's state-and-federal programs that effectively met the goals of high productivity and significant accomplishment in cooperative studies of U.S. oil-producing basins.

Other Presentations The paper, "Optimizing Reservoir Management," was presented to the Illinois SPE Chapter in February 1992. The paper signaled a new level of approach and integration in geologic engineering; it was based on results from the ENR-USDOE project. Another invited paper, "The Improved Oil Recovery and Reservoir Characterization Program in Illinois," was given at the Appalachian Technical Symposium in West Virginia.

Poster displays showcasing the progress of the ISGS Oil and Gas Program were presented at the Illinois Oil and Gas Association Meeting in March 1992. The event was attended by about 400 local geologists, oil company operators, and service company representatives.

In June, Oltz talked to the Illinois Oil Producers Association and Grube spoke before the Kentucky Oil and Gas Association. Their topic, the Improved and Enhanced Oil Recovery Program in the Illinois Basin, was also presented by Grube to the Illinois Stripper Well Owners and Royalty Association.

The Oil and Gas Section hosted the joint ENR-USDOE workshop, "Identification of Unrecovered Mobile Oil," in Mt. Vernon in November 1991. The workshop was attended by 145 Illinois operators.

The semi-annual PAC-TAC committees (advisory to the ENR-USDOE project) met in Champaign in October 1991. Research results were summarized. Demonstrations covered geologic and engineering modeling software and experiments using CO₂ to increase oil recovery.

In September, R. Michael Ray, Associate Director of USDOE's Bartlesville Project Office, visited ISGS for technical review of the ENR-USDOE project. E. Wayne Bahr, ENR's manager of the project, and ISGS management also attended. Several of the more than 40 projects that made up the effort were presented for review. Ray assessed the project as "exceptional."

The Oil and Gas Section presented two papers and one poster at the Eastern Section AAPG meeting held in Pittsburg in September 1991. "Depositional Facies and Hydrocarbon Reservoir Compartmentalization of the Mississippian Aux Vases Formation at King Field, Jefferson County, Illinois," was Leetaru's topic. Grube's talk covered, "Reservoir Characterization of Multiple Bar Sandstones in the Mississippian Cypress Formation Tamaroa Field, Perry County, Illinois." Beaty presented the poster paper, "Effects of Diagenesis on Reservoir Quality Within Two Cypress Reservoirs in the Illinois Basin." His co-authors were McGee and Seyler. The presentations were also made to the Indiana-Kentucky Geological Society during the same month.

Characteristics of Chlorite Interlayered with a 7Å Mineral as Found in Sandstone Reservoirs, Moore, Hughes A poster session was presented at the annual meeting of the Clay Mineral Society of America in Houston, Texas, to report on the distribution of a recently discovered clay mineral that is present in most Illinois reservoirs. Other reservoir properties that are correlated to this chlorite and the effect of this chlorite on recovery of oil were summarized.

Varieties of Chlorites in Sandstone Reservoirs, Moore, Hughes This paper was presented at annual meeting of the North Central Geological Society of America in Iowa City. The discussion covered the range of variation in the composition and atomic structure of chlorites that are found in Illinois reservoirs and the impact of these chlorites on oil recovery.

OTHER ENERGY SOURCES

Evaluation of Gas Potential of the New Albany Shale (Group) (Devonian-Mississippian) in the Illinois Basin, Frankie, Lumm This cooperative study sponsored by the Illinois Basin Consortium is partly funded

by the Gas Research Institute and involves the Indiana, Kentucky, and Illinois Geological Surveys. The objectives of the research are to compile, review, update, and reinterpret all data (published and unpublished) useful for assessing the gas potential of the New Albany Shale in the Illinois Basin. The contract ended in May 1992; the final report is due in September 1992.

Products include a structural features map of the Illinois Basin, five statewide stratigraphic cross sections, maps depicting New Albany Shale gas production and core locations, and isopach and structure maps of the New Albany Shale at a scale of 1:1,000,000. A stratigraphic database for the New Albany Shale, created from information on 5,223 wells, will be used to assess the gas potential of the New Albany Shale.

Coal Bed and Coal Mine Methane, Frankie The ISGS supplied information on coal mine and coal bed methane to operators attempting to evaluate the potential for gas production in Illinois. Analyses of the gas content of coal beds, information on thickness and depth of coal seams, and maps of abandoned coal mines were provided. A handout with basic information and a list of related publications on the subject have been supplied. Currently, seven operators seeking to assess or produce methane have drilled into abandoned coal mines in Christian, Franklin, Montgomery, Saline, Sangamon, and Williamson Counties.

HYDROGEOLOGY

Nearly one-half of the citizens of Illinois obtain their household water supplies from approximately 4,000 public water supply wells and 500,000 private wells. Groundwater in Illinois is usually obtained from unconsolidated deposits of sand and gravel, mainly in glacial deposits, or limestone or sandstone formations of the underlying bedrock. Knowledge of the geology and hydrology of aquifers in Illinois is fundamental for delineating, quantifying, and protecting the state's groundwater resources.

The groundwater resources program looks at both regional and local aquifer systems. In FY92, research continued on aquifers of the Prairie Aquigroup in northwest and north-central Illinois and on the shallow bedrock aquifers of northwest Illinois. These projects were funded by the Illinois Department of Energy and Natural Resources (ENR) through the Aquifer Assessment Program. A long term study of the flow system within the Illinois Basin also got underway.

Local aquifer systems are studied in response to the needs of municipalities to increase their groundwater supplies. The field work for these studies often involves using geophysical techniques. Partial funding is provided by the communities requesting assistance. In FY92, five studies were completed and the sixth began; all are in Kane County.

Responses to requests for service reached a new high in FY92. Telephone responses averaged 120 calls per month; letter responses were up by 70% to 260 for the year; and groundwater possibility reports were up by 20% over FY91.

Groundwater Systems

Characterization of Subsurface Aqueous Environments, Heidari, Heigold This program involves building and testing models to automate characterization of the subsurface environment. A program for analyzing aquifer test data has been adopted to handle anisotropy. Most aquifers are anisotropic, which means that the rate at which they transmit water changes with direction. The program currently being tested allows quantification of these directional differences.

Modern Fluid Dynamics in the Illinois Basin, Heidari, Kolata, Herzog, J. Treworgy, Lasemi, Cartwright Knowledge of the structural and stratigraphic framework of the Illinois Basin has developed over many years of outcrop and subsurface studies. The nature and distribution of the more than 120,000 cubic miles of sedimentary rocks that fill the basin, particularly at shallow depths, are well documented. In contrast, much less is known about the fluids that have moved through the basin and evolved hydrologically as the basin subsided, infilled, and deformed during the last 500 million years.

Like many interior cratonic basins, the Illinois Basin contains widespread aquifers that have remained permeable through millions of years. Evidence indicates that these aquifers have stored and transferred large volumes of groundwater in the geologic past, and they continue to do so. Thus knowledge of fluid flow is economically important, because it bears on water resources, petroleum and mineral migration, geothermal resources, and toxic waste disposal.

Program goals are to (1) describe the hydrostratigraphy, hydrology, and geochemistry of the basin; (2) describe the movement of fluids at various times in the geologic past and present; and (3) determine the relationship of basin hydrogeology to mineral, petroleum, and water resources and environmental concerns.

Work on the project has just begun. The ISGS has joined a consortium on basin hydrological research through the UI-UC Geology Department: the Industrial Consortium for Research and Education. The consortium provides access to software for modeling basins in cross sections and access to a minisupercomputer. Core samples have been selected for porosity and permeability analysis to provide data for the model.

Groundwater Assessments

Prairie Aquigroup Assessment, D. Larson, Herzog, Vaiden, Chenoweth, Anderson, Xu Initial focus of the 5-year, ENR-sponsored study was on the Green River Lowland, which includes parts of Whiteside, Lee, Rock Island, Bureau, and Henry Counties. Although significant groundwater resources are found in this area, it is the least understood of the major bedrock valleys in the state.

Studies made of the area in the 1950s are being updated by incorporating all available well data, including new data and geophysical logs from wells drilled by the Illinois State Water Survey for a companion project, with limited seismic data on the lowland area. One new well, in an area of sparse data, showed

that the valley was 100 feet shallower than scientists thought when the 1950 map was drawn. Results of the study were presented at the North-Central CSA meeting.

The second area selected for study encompasses Boone, Winnebago, and McHenry Counties—an area that has the State's highest priority for groundwater protection. Boone and Winnebago Counties, which were well mapped in 1980, only need updating; mapping of McHenry is a new undertaking. Staff have verified well locations in Boone and McHenry Counties, compared currently available data with data from the 1980 study of Boone County, and mapped three 7½-minute quadrangles of McHenry County.

Upper Bedrock Aquifer System in Northern Illinois, T. Larson, Graese, Orozco, E. Smith A 3-year investigation of the hydrogeology of the shallow carbonate rock groundwater resources in northern Illinois began in 1989. These aquifers constitute a highly used groundwater resource, but they are also highly susceptible to contamination.

Investigations in the region underlain by Silurian-age bedrock in northwestern Illinois are nearly complete. Maps have been developed to show the elevation of the bedrock, thickness of the Silurian rock, and thickness of the weathered zone, which has strong potential as an aquifer. Work also began on a similar investigation in Kankakee and Iroquois Counties of northeast Illinois.

Bedrock Valley Aquifers of Illinois, Herzog, Chenoweth Significant sand and gravel aquifers are commonly found in bedrock valleys of Illinois. To help locate these buried valleys, the ISGS has updated the statewide bedrock topography map. The last map was produced in the 1950s, when significantly less data were available. This year, all recently published data were incorporated into the map. It is now being digitized to make future updates much easier. A computer-drawn version of the map is expected in FY93.

Groundwater Resources in Kane County, T. Larson, Orozco Groundwater resources in the glacial drift and shallow bedrock of Kane County were the focus of several detailed studies. Supported by funding from the county, local municipalities, and the Division of Water Resources of the Illinois Department of Transportation, these studies successfully identified aquifers with large potential groundwater supplies. Final reports were published for the Aurora, St. Charles, and Geneva-Batavia areas and the Fox River corridor.

Geophysical Study of North Aurora, T. Larson, Orozco A seismic study was funded by the village to locate one of the shallow aquifers in south-central Kane County. The study was completed in December. Data from 27 reversed seismic refraction profiles revealed that the St. Charles bedrock valley was located about 1 mile farther west than previously thought. Three locations in the valley were recommended for test wells.

Geophysical Study of Gilberts, T. Larson, Orozco A seismic study was funded by the village of Roberts to locate the Gilberts buried bedrock valley in north-central Kane County. Data from 11 seismic spreads will define the location of the buried valley with its major sand and gravel aquifer. After the data are analyzed, test well locations in the valley will be recommended. The study will be complete early in FY93.

Will and Southern Cook Counties, E. Smith, McLean, GMDC staff Under an agreement with the Illinois State Water Survey (ISWS), the ISGS completed geologic and hydrogeologic maps and cross sections of Will County and a part of southern Cook County. A computer database of water well records and other subsurface data were developed to update existing information and to facilitate map construction. New maps of bedrock topography, drift thickness, and sand and gravel thicknesses were provided to the ISWS. A report summarizing the results of the investigations and describing the hydrogeologic conditions of the area was included with the maps and cross sections.

The map of the shallow dolomite aquifer thickness aided the ISWS in hydrological modeling of the study area. The four generalized cross sections provided with the report assisted with portraying the complexity of the deposits found below land surface within the glacial drift.

Springs in Illinois, P. Reed (ISGS); Webb, Weitzel (INHS) Springs are naturally occurring, collective points of groundwater discharge; they appear at the surface as flowing water. A 1-year study of springs, conducted in cooperation with the Illinois Natural History Survey and funded by the Nature Preserve Commission, determined momentary flow, water chemistry, and biological diversity at six springs located in Hardin, Jackson, Gallatin, and Union Counties in southern Illinois. Radiocarbon age of spring water at two sites and the radiocarbon age of sediment at one site was also determined. A unique new species of ostracod was found at one spring. The physical characteristics of the springs were classified using topographic and geologic setting, structure type, and discharge rank.

Geologic, Geophysical, and Hydrogeologic Investigations for a Municipal Groundwater Supply for Danville, Illinois, Kempton, D. Larson (ISGS); Meyer (ISWS); others An October 1991 meeting was held with officials of Inter-State Water Company and its parent company, Consumers Illinois Water Company, regarding Danville's water shortage and reservoir nitrate levels. The result is a compilation of all information gathered since earlier (1988) work with Inter-State. Stratigraphic position and distribution of the principal sand and gravel units that may be utilized as aquifers have been identified in the region from Danville north to the Mahomet Valley. The company's short and long term groundwater resources are evaluated in the report, which is in review by the water company. It will be published in the ISGS Open File Series.

Technical Assistance

Resistivity Surveys, P. Reed Resistivity (electrical) surveys are useful for interpreting water quality in earth materials and in determining the lithologic character of alluvial and glacial drift deposits. Surveys for sand and gravel aquifers were conducted at 51 sites where test drilling had failed to reveal an adequate groundwater supply. Included were studies for 10 municipalities, two public supplies, four industries, 18 farms, and 17 private acreages throughout Illinois.

Borehole Geophysics, P. Reed, Orozco The most common geophysical data used by geologists, hydrologists, and engineers are borehole logs—graphic records of the in situ chemical, physical, and acoustical characteristics of saturated and unsaturated earth materials. Borehole logs are fundamental in the correlation of the materials. They are extensively used to evaluate aquifers and to aid in electrical earth resistivity surveys of water-bearing sand and gravel deposits. This fiscal year, 42 borehole logs were run at 31 sites.

Technology Transfer and Information Services

Service Requests for Groundwater Resources and Other Geologic Information, Brower, Herzog, Reed, E. Smith, Vaiden Requests for information were received from well drillers, farmers, and other citizens as well as industries and government agencies desiring to locate, develop, and use groundwater resources. Responses included more than 1,400 phone calls, 260 letters, and 80 groundwater possibilities reports; 16 sieve analysis reports were written covering 55 samples for 16 municipal test holes and three irrigation holes. Approximately 70 people visited staff of the Hydrogeology Section to seek information.

INDUSTRIAL AND METALLIC MINERALS

From 1981 to 1990, production of minerals other than fuels added \$5.02 billion to the Illinois economy and sustained thousands of jobs in the state's mining industry. Nonfuel mineral production, including the value-added products of cement and lime, decreased from a record \$665.1 million in 1990 to \$609.5 million in 1991—an 8% decrease of \$55.6 million.

Illinois continues to rank first among the states in the quantity and value of fluorspar, industrial sand and gravel, and tripoli produced. In recent tabulations, Illinois ranked third in fullers' earth, fourth in crushed limestone and dolomite, fourth in peat, seventh in lime, eighth in construction sand and gravel, and eighth in cement. Illinois ranked 16th among the states in value of mineral commodities produced in 1991.

Mineral resource activity in Illinois during 1991-1992 included exploration, acquisition, and expansion in the private sector along with accelerated research, mapping, and mineral assessment by state and federal agencies. Acquisition of new reserves in Illinois, particularly by aggregate and industrial sand producers, was basically restricted to properties adjacent to existing operations. Another continuing practice was the purchase of small companies by larger ones.

Other purposes were reported for land acquisition: Du Page County voted to buy the Elmhurst-Chicago quarry and underground mine site and use it for flood water storage.

High-calcium limestone, suitable for use in desulfurization processes and other chemical application and high purity, high brightness carbonates for fillers and/or whiting agents, claimed interest statewide. Crystal Products Company formed to develop high calcium limestone deposits in Hardin County and produce a skid-resistant, surfacing material from an associated calcareous sandstone. Quincy Carbonates Inc., operating south of Quincy in Adams County, prepared for entry into the mineral filler market.

In southern Illinois, Ozark-Mahoning Company, a subsidiary of Atochem North America and the major U.S. producer of fluorspar, operated three mines to feed their mill at Rosiclare, in Hardin County. It is reported that mining in their No. 1 mine, in the Cave-in-Rock bedded fluorspar district, is currently below 400 meters and that recent drilling discloses ore deposits at least 40 meters deeper. At the end of 1991, the company reduced the number of core-drilling rigs from five to two, largely in response to the importation of acid-grade filter cake from China. Ozark-Mahoning proceeded with the modernization of the Rosiclare processing plant and continued testing the use of column flotation with promising results.

Shawnee National Forest officials reported that only one permit (fluorspar) was issued for prospecting in the forest during the year. Leasing was reported for corporate entities not previously known to be actively interested in the rare earths and specialty minerals of the Illinois-Kentucky Fluorspar District. New leasing activity was also reported in northwest Illinois, in and around the Upper Mississippi Valley Zinc-Lead District that has been inactive since the mid 1970s.

Kaolin or ball clay was discovered near Sterling in Whiteside County in early 1992. This clay was discovered by ISGS geologists investigating possible sources of the raw material for a wide range of Native American artifacts found in Northwestern Illinois. The mineral is thought to occur within the Neda Formation (Ordovician). The extent and purity of the deposit is not known, but the clay industry is interested in this potentially major development.

The search also continued to find better quality, lower cost materials for the production of brick and red-fired ware.

Mineral Resource Assessments

Conterminous U.S. Mineral Assessment Program (CUSMAP) Paducah Quadrangle, Eidel, Baxter, staff The joint meeting of the Paducah CUSMAP Project, the Illinois Basin Consortium, and the U.S. Geological Survey (USGS) Evolution of Sedimentary Basins Program was held in St. Louis in January 1992. The results of collaborative research in the Illinois Basin were presented by the state geological surveys of Illinois, Indiana, Missouri, Kentucky and the USGS. The Paducah Quadrangle was the locus of CUSMAP assessments of fuels and other minerals.

The Paducah 1° × 2° Quadrangle includes all of Illinois south of the latitude of Benton. The method and steps employed involved compilation of all existing geological, geophysical, and geochemical data; identification and acquisition of new information to fill gaps in the database; and in-depth evaluation of the fluorspar, barite, base metal, beryllium, thorium, rare earths, industrial minerals, coal, and oil and gas potential of the Paducah Quadrangle.

Digital mapping techniques and the Illinois Geographical Information System (IGIS) were used for the Paducah assessments, which represent the first successful use of GIS methods to produce mineral assessments in the nationwide program. Abstracts of all CUSMAP projects were published in USGS Open File Report 92-1, *Mineral Resources of the Illinois Basin in the Context of Basin Evolution*.

Database Development for CUSMAP, Pool, Stiff, McKay, Denhart The ISGS has coordinated the digital database development for the CUSMAP project for the past 5 years. Working with the USGS and other state surveys, ISGS staff utilized the Illinois Geographic Information System (IGIS) to automate and store the maps and well logs in digital format for the CUSMAP project. This database was used to construct 19 mineral resource models. Conceptual approaches to these models were designed by teams of mineral resource experts from the participating surveys.

A total of 52 geologic maps and model results, available as printouts from the electrostatic plotter, are being distributed through the ISGS Open File Series.

Paducah CUSMAP Products Maps, cross sections, and models that were prepared for display at the public meeting are now available in preliminary form. Two hundred forty-four maps were distributed to three state surveys and the Illinois State Library; 122 maps were ordered by the USGS; 119 maps were ordered by private firms and the U.S. Bureau of Mines. The total was 485 maps.

Products include the following:

- **Bedrock Geologic Maps, Nelson, Mapping and Digital Cartography Section staff** A full color, 1:250,000-scale, bedrock geologic map of the Paducah 1° × 2° Quadrangle was prepared for the assessment. The report accompanying this map is in editorial review and will be published in FY93, if funds are available. Four, 1:100,000-scale, black and white quadrants will represent the bedrock geology of the Paducah Quadrangle for this report. The full-color version will be published at a later date, probably as a part of the USGS-ISGS Bulletin on the Paducah Quadrangle.

- **Surficial Deposits and Stack Map, Berg, Greenpool** A stack-unit map illustrating sequences of geologic materials to a depth of 50 feet, and a generalized surficial deposits map have been prepared for the Paducah CUSMAP project. The first map is currently being edited; the latter is in final review.

- **Mines, Prospects, and Mineral Occurrences, Johnson (USGS); Anderson (KGS); Baxter (ISGS); McFarland (MGS)** Data on all known mines, prospects, and

other mineral occurrences were entered into the USGS Mineral Occurrence Data System (MODS). Illinois sites in the database include fluorspar, lead and zinc (270), tripoli (121), sand and gravel (60), clay and shale (106) and limestone (33). For each locality, there are 34 different data fields that characterize the deposit as to site, site type, location, deposit type, commodities present, local and regional geology, host rock lithology and age, and age of mineralization. Site locations and most of the data fields were converted from MODS to ARC-INFO for use in GIS assessments. The report, "Mine Prospects and Occurrences of Metallic Minerals, Barite, and Fluorite in the Paducah Quadrangle," was prepared for the public meeting.

- **Cross Sections in the Paducah Quadrangle, J. Treworgy, Whitaker, Sargent** Three structural cross sections, traversing the Paducah Quadrangle of southern Illinois and adjacent parts of Kentucky, Missouri, and Indiana, were presented at the public meeting for the CUSMAP Project held in St. Louis. The sections, which are based largely on key, deep wells, were constructed as part of the IBC Cross Section Project and the CUSMAP Project.

For the first time, a set of regional cross sections for this mineral-rich area is available to the public. Potential oil and gas plays are indicated on the sections. The sections are being used by other researchers to plot geochemical data and to help delineate potential zones of mineral occurrences.

The cross sections were also presented in Iowa City at the Annual Meeting of the Geological Society of America, North-Central Section, in April 1992.

- **Subsurface maps of the Paducah Quadrangle, Sargent, others** Results of isopach, lithofacies, and structural mapping of more than 12 units of the Cambrian, Ordovician, and Devonian Systems in the Paducah Quadrangle were presented as a poster at the joint meeting held in St. Louis in January 1992. Units mapped include the St. Peter Sandstone, Everton Dolomite, Ottawa Supergroup, New Albany Shale, Lower and Middle Devonian Series, Mt. Simon Sandstone, Eau Claire/Bonnerterre Formation, and Knox Group. Many of these maps are of units known to be host rocks for mineral deposits in nearby districts or of strata that show a strong potential to be mineralized in this area. Other units may have acted as conduits for the transport of ore-forming fluids from their source to the site of deposition. A map showing the morphology on the surface of crystalline basement was also produced. Digital versions of some maps were used to develop models for the deposition of ore in these units.

- **Magnetic and Gravity Study of Quadrangle: Illinois, Indiana, Kentucky, and Missouri, Heigold (ISGS); Hildenbrand, Kucks (USGS)** Magnetic and gravity data in the Paducah Quadrangle provide a geologic picture of the subsurface that indicates a long and complex tectonic and magnetic history. A prominent continental-scale magnetic lineament (the South-Central Magnetic Lineament) possibly delineates a northwest-trending shear zone that controlled intrusion in Pre-Cambrian time. Two Early Cambrian rifts (the Reelfoot and the Rough Creek) trend into the study

area. Interpreted structures and magnetic basement depth suggest that the Reelfoot Graben bends eastward to join with the Rough Green Graben. Paralleling the South-Central Magnetic Lineament to the southwest is the pronounced gravity lineament (the Paducah Gravity Lineament) that may represent dense mafic intrusions emplaced along northwest-trending faults and axial faults of the Reelfoot Graben. The age of these intrusives is interpreted to be Cambrian or younger. Strike-slip motion along these northwest-trending faults is suggested by deflections of magnetic anomalies along the margins of the Reelfoot Graben.

Post-rifting geology is characterized by thick sequences of sedimentary rocks as evidenced by deepening of magnetic basement (>6 km) in the Rough Creek Graben. Large, shallow magnetic intrusions of post-rift age may be present in or near the Wabash Valley Fault System and in southwestern Illinois. A high-pass magnetic anomaly map delineates as many as 14 shallow (<1 km), plug-like intrusions in the eastern part of the study area. Three of these shallow intrusions coincide with Hicks Dome and Omaha Dome in Illinois and Coefield in Kentucky. Omaha Dome and the Coefield shallow intrusives may have mineral potential similar to that at Hicks Dome.

• **Lineament Map, Stohr** The map, "Interpretation of Side-Looking Airborne Radar and Satellite Imagery of the Paducah Quadrangle for Lineaments," was presented at the St. Louis meeting. Previously unrecognized structural features were mapped using imagery that "sees through" vegetation.

• **Mineral Deposit Models, ISGS, KGS, MGS, USGS staff** Early in the course of the project, purely descriptive models were prepared for selected mineral deposits in the Paducah Quadrangle and for deposit types that may be present. From these descriptive models, diagnostic criteria that can be represented by a single point or areally defined were chosen and assigned values related to their relative importance as indicators of potential GIS techniques to define appropriate point and areas, provide buffers zones, assign weights, and produce layers of data required for full assessment. Numerous new areas of potential mineralization were identified. The following maps and data were on display at the public meeting and are available as electrostatic plots from the ISGS.

• **Coal Resources in the Paducah Quadrangle, C. Treworgy, Bargh, Coats, Jacobson** Mapping and assessment of coal resources in the quadrangle were carried out in conjunction with CUSMAP research. The ISGS Geographic Information System (GIS) software was used to compile data on coal resources and, on the basis of geologic and engineering parameters, rank the development potential of resources. Six map products were completed, including resource and development potential maps for the Herrin, Springfield, Davis, and Dekoven Coals; a map of miscellaneous coal outcrops; and a map of the thickness of the Pennsylvanian strata. An interactive, menu-driven computer program was developed to allow users to access the coal database and determine the location and quantity of coal that meet various parameters for quality and minability.

• **Oil and Gas Resources, Crockett, Oltz, R. Howard (ISGS); Mast (USGS); Rupp (IGS); Noger (KGS)** A poster session was presented at the St. Louis meeting entitled, "Oil and Gas Potential in the Paducah Quadrangle." The oil and gas assessment defined the regions within the Paducah Quadrangle where individual oil and gas plays were most likely to exist: (1) areas where Pennsylvanian and Mississippian stratigraphic, structural, and combination traps (the most prolific producing zones in the Illinois Basin) were likely to exist; (2) areas where faulted and fractured plays were likely to occur; (3) areas where Devonian, Silurian, and upper Ordovician carbonate plays (the deeper, sparsely explored yet oil-productive strata in the Illinois Basin) could occur; (4) areas where the Silurian reef trend is interpreted to occur; and (5) areas where plays in Ordovician and Cambrian rocks, (strata older than known oil-producing horizons) might occur. This category includes play types such as stratigraphic and structural traps related to basement paleotopography, unconformities, and plays associated with the ancient Reelfoot Rift structure.

The presentation highlighted oil and gas exploration concepts, described examples of known reservoirs, discussed effective and potential hydrocarbon source rocks in the region, and interpreted areas where multiple plays may be present in the Paducah Quadrangle.

• **Fluorspar and Base Metal Resources, Baxter, Pool (ISGS); Anderson (KGS); Hayes (USGS)** Models were prepared for GIS assessment of the resource potential for each of the two major types of fluorspar orebodies known in the Illinois-Kentucky Fluorspar District: vein and bedded deposits. Diagnostic criteria that were weighted and used in the assessment were (1) tectonics (relationships of known deposits to the New Madrid Rift System); (2) structure (relationship to mapped faults (veins) and to graben-bounding faults (bedded model)); (3) amount of fault displacement; (4) SAR and LANDSAT interpreted structures; (5) northeast-southwest orientation faults and grabens; (6) domal structures and noses; (7) mineral occurrences; (8) geochemistry; and (9) presence or absence of favorable host rocks. The GIS weighted sum of the criteria favorable for mineralization constitute maps of mineral resource potential: they indicate many new areas of fluorspar and base metal potential.

• **Metalliferous Ore Deposits in the Dutchtown Limestone, Sargent, Eidel (ISGS); LaRock, Goldhaber (USGS)** Models were developed to evaluate the potential for Mississippi Valley-type (MVT) lead-zinc-silver mineralization of three stratigraphic units of the Dutchtown formation in the Paducah Quadrangle. The Dutchtown Limestone was digitally analyzed using diagnostic criteria that included suitable host rocks, presence of aquifers, absence of aquitards, presence of faults, occurrences of MVT mineralization, positive geochemical indicators, and proximity to Precambrian crystalline basement knobs or shallow depths to basement. These factors were given weights relative to their importance in the formation of a mineral deposit. These weighted factors were plotted on a series of maps and summed to determine the most likely areas

for the occurrence of MVT mineralization in the Dutchtown Limestone. A number of previously unsuspected areas of mineralization were identified.

• **Limestone and Dolomite Resource Assessment Models, Baxter, L. Smith, Stiff (ISGS); Dever, Anderson (KGS); Rueff, McFarland (MGS)** A limestone and dolomite resource map was compiled and digitized at 1:100,000 scale to show the distribution of limestone and dolomite formations with potential as sources of construction aggregate, high calcium limestone, and building stone. This 1:250,000-scale map, the stack unit map, and the mines and prospect database provided the basic data for construction of GIS models for three categories of use. Diagnostic criteria used in evaluation include (1) distribution of rock of known quality and use potential, (2) thickness of overburden, and (3) occurrence data (location of quarries). These maps constitute a detailed catalog of potential limestone resources for the region.

• **Sand and Gravel Resource Assessment Models, Masters, Rueff (MGS); Olive (KGS); Baxter (ISGS); Anderson (KGS); McFarland (MGS)** GIS models showing the potential for deposits of alluvial sand and gravel, and chert gravel were prepared using data on distribution, unit thicknesses, quality, known occurrences, and overburden thickness for each commodity. The assessment models were derived from a sand and gravel resource map (scale 1:250,000) that was based on surficial and stack-unit maps prepared for the Paducah CUSMAP area; drilling data were added. Maps illustrating the potential for each sand and gravel product were presented at the St. Louis meeting.

• **Clay Resource Assessment Models, Hughes, Baxter (ISGS); Olive (KGS); Rueff (MGS); Anderson (KGS); McFarland (MGS)** A clay and shale resource map (scale 1:250,000) showing the distribution of potential sources of clay and shale commodities was prepared by combining information on the bedrock geology map and the stack-unit map. Data on distribution, occurrences, quality, and overburden thickness were used to construct quantitative GIS models on which to base assessments. Separate models were prepared for absorbent clay (fullers earth), ball clay (including kaolin), common clay and shale (brick and tile), and lacustrine clay (for earthen liners). Maps illustrating the potential for each clay were presented.

Limestone and Dolomite Resources

Limestone and Dolomite Resources in Northern Illinois, Mikulic As part of the \$3.6 billion Tunnel and Reservoir Plan (TARP) of the Metropolitan Water Reclamation District of Greater Chicago, the U.S. Army Corps of Engineers is conducting a geotechnical study in connection with plans for the partial development of a reservoir from McCook Quarry owned by Vulcan Materials. The study involves numerous cores drilled to determine geological and geophysical characteristics of the stone. At the request of the Corps and their consultants, Mikulic provided stratigraphic information and guidance in the logging of cores. This required several visits to the McCook Quarry near Chicago during the 1991-1992 report period.

Acquisition and Study of TARP Cores, Mikulic, Eidel, Norby, Hughes Storage facilities are sorely needed for cores from TARP and related projects. These materials, scheduled for disposal by October 1992 and offered to ISGS at no cost, represent a unique geotechnical database for Cook County and surrounding areas. The preservation and study of these cores will be of continuing value in geotechnical studies such as those for evaluation of general construction projects, feasibility studies of underground mining of aggregate, and special projects such as the proposed Lake Calumet Airport.

Aggregate Resources of Kane, Du Page, and De Kalb Counties, Mikulic New sources of aggregate are being sought to offset the depletion of present reserves and environmental constraints on the development of new quarry sites in much of the Chicago metropolitan area. Private companies have shown considerable interest in Kane, Du Page, and De Kalb Counties, despite greater haulage distances from the urban center.

Compilation of existing data, including geotechnical information generated previously for the proposed Illinois site for the Superconducting Super Collider, has identified several new quarry or underground mining sites. An enhanced understanding of the geology of the Silurian and Ordovician rocks can potentially aid in the development of these and other new sites.

Sand and Gravel Resources

Sand and Gravel Resources of Illinois, Masters Sand and gravel research was largely restricted to the CUSMAP assessments carried out in southern Illinois.

Sand and Gravel Service, Masters Information on the location, character, and uses of known and potential sand and gravel deposits was provided to a variety of individuals, including producers, users, landowners, environmental groups, and state and federal agencies. Many requests for information received by phone or from walk-in visitors could be handled at once. Others required compilation of data from ISGS files, in which case the information was provided in a letter or by fax.

Clay Mineralogy and Clay Resources

Occurrence of Kaolin in the Neda Formation, Hughes, Moore Potentially valuable kaolin deposits have been located within the Neda Formation of the Maquoketa Group in northwestern Illinois. Information from the Quaternary clay mineralogy database and from ISGS efforts to map bedrock and define local water resource availability was used to estimate the area of occurrence of this kaolin. It is hoped that release of the information to the public will encourage development.

Clay Minerals Business, Hughes, Moore, White Support of clay-mineral-based industrial activity in Illinois included consultations, analysis of samples, phone conversations, and the assembling and sending of operations-related data. Recent efforts have focused on continued support for the establishment of new mines. A chapter on ceramic raw materials was written for the

sixth edition of *Industrial Minerals and Rocks* (Society of Mining Metallurgy and Exploration).

Fluorspar and Metal Resources

Exploration Drilling Records, Northwestern Illinois Zinc-Lead Mining District, Bradbury The U.S. Bureau of Mines atlas (drilling logs and maps) of the zinc-lead district is a useful compendium of exploration drilling data.

Recent review of the data indicated, however, that a number of unsystematic errors, discrepancies, and omissions had to be identified and corrected. This entailed an intensive search of the atlas for errors (logs without map locations, spot locations without logs, misplotted holes). Atlas records were also checked against various records filed with the ISGS by mining companies and independent operators to identify logs overlooked by the Bureau in compiling the Atlas.

Intrusive Breccias at Hicks Dome, Hardin County, Illinois, Bradbury, Baxter Hicks Dome is a circular, uplifted structure marked by numerous occurrences of intrusive breccia, some of which are mineralized. Intrusive breccias formed at this location because of the explosive release of gases, probably from a deeply buried alkalic magma.

Forty-five breccias bodies have been mapped in an area approximately 2 miles square. Most are nearly vertical breccia dikes that range from a few inches up to 10 feet in width; some are bodies of undetermined shape. Some breccias exposures are weakly mineralized; more strongly mineralized breccia (F, Pb, Zn, Ba, Nb, Be, Ti, Th, and REE) is known to occur at depth.

A report describing the physical and chemical character of Hick Dome breccias, related mineralization, and modes of origin was produced as ISGS Circular 550; it was printed in July 1992.

Silica and Industrial Sand Resources

Structural History, Stratigraphy, and Origin of Tripoli (Microcrystalline Silica) Deposits of Southwestern Illinois, Berg (Montana Bureau of Mines and Geology); Masters (ISGS) Illinois leads the states in production of tripoli for use in abrasives and of ultra pure, high brightness tripoli ("microcrystalline silica") for use as a filler and extender in paint, rubber, and other formulations.

Economic deposits of tripoli occur mainly in the Clear Creek Chert of Lower Devonian age exposed on the southwestern margin of the Illinois Basin in Union and Alexander Counties. As mined, Illinois tripoli consists of quartz crystals, less than 2 μm in length, constituting a white porous rock containing more than 98% SiO₂. The origin of tripoli has been attributed to intense weathering, but it is now thought that low temperature, hydrothermal alteration may be the major factor. Recent geological mapping in the area, under the COGEOMAP program, further indicates that localization tripoli is controlled by minor faults.

A report, completed during an earlier period, is now through peer review and scheduled for publication by the ISGS.

Technology Transfer and Information Services Workshop: "Working to Ensure the Availability of Constructional Materials: Demand, Resources, Land Use Planning, Environment, Economics," Leighton, Bhagwat, Eidel, Baxter, Mikulic ISGS staff attended and participated in workshop sponsored jointly by the U.S. Geological Survey (USGS) and U.S. Bureau of Mines. The workshop, held in St. Louis during September 1991, was planned in cooperation with seven midcontinent states (Arkansas, Illinois, Kansas, Kentucky, Missouri, Oklahoma, Tennessee). It dealt with various issues involved in providing the quantities of constructional aggregate (crushed stone, sand and gravel) needed to meet future requirements for building and rehabilitation of infrastructure in urban areas where environmental constraints are most restrictive. Participants included resource specialists, state regulatory agencies, local and regional planners, and aggregate producers from the seven states. In addition to the ISGS, the Illinois Department of Mines and Minerals, Illinois Environmental Protection Agency, and Illinois Department of Transportation participated.

Dr. Leighton presented an issue paper dealing with resource evaluation and stressing the need for geologic mapping. Dr. Bhagwat presented a portion of an issue paper on economics of materials used in construction. He also led a panel discussing cost factors in the use of constructional materials. Eidel was a member of a panel dealing with information essential to resource availability. All contributed their remarks to a USGS publication on the results of the workshop.

Industrial Minerals, Today and Tomorrow—The Raw Materials to Build the Upper Midwest, Eidel An Industrial Minerals Workshop, sponsored by the USGS in cooperation with the USBM and the Minnesota Geological Survey, will be convened in Minneapolis in September 1992. Eidel, who serves on the planning committee, will present an ISGS exhibit highlighting the GIS-produced industrial minerals potential maps of the Paducah Quadrangle.

Assessment of the Clay and Shale Resources of the Paducah Quadrangle, Hughes, Baxter, Stiff (ISGS); Olive (KGS); Rueff (MGS); Anderson (KGS); McFarland (MGS) A talk and accompanying poster exhibit were presented at the joint meeting of the Paducah CUSMAP Project, the Illinois Basin Consortium, and the USGS Evolution of Sedimentary Basins Program held in St. Louis in January 1992. Four clay resource models and GIS-generated maps showing the potential clay resources of the Paducah Quadrangle were discussed.

Economic Potential for Industrial Minerals in the Paducah Quadrangle, Southern Illinois and adjacent Kentucky and Missouri: The Results of GIS Composites of Resource Models, Hughes, Masters, Baxter, Eidel, Berg, Pool, Smith, Stiff (ISGS); Anderson, Dever, Olive (KGS); McFarland, Rueff (MGS) Twelve posters illustrating areas of potential for discovery of new resources of industrial minerals were exhibited at the 28th Annual Forum on the Geology of Industrial

Minerals in West Virginia. Commodities covered include limestone and dolomite for aggregate; building stone for construction and high calcium uses; alluvial sand and gravel and chert gravel for construction; structural clay and shale, absorbent clay, ball clay, and containment clay for lining disposal sites; tripoli; and vein and bedded fluorspar deposits. The Forum attracted many independent and corporate geologists and explorationists who can best use this information to develop new ventures in the region.

Microcrystalline Silica (Tripoli) Deposits in Southwestern Illinois, Berg (Montana Bureau of Mines and Geology); Masters (ISGS) A short version of the report was presented at the 28th Annual Forum on the Geology of Industrial Minerals in West Virginia in May 1992. A camera-ready copy was delivered for inclusion in the *Transactions*.

A New Kaolin from the Neda Formation of Northwestern Illinois, Hughes, Moore (ISGS); Berries (UI-CU, Anthropology); Farnsworth (IL State Museum) This paper, presented at the 28th Annual Forum on the Geology of Industrial Minerals in West Virginia, represented a public release of information and a summary of current knowledge about the extent, quality, and economic potential of this newly discovered clay deposit at Sterling, Illinois.

Mineral Resources of the Lake Calumet Area and Possible Impact on Proposed Third Airport for the Chicago Area, Masters, Mikulic, Hughes, Baxter Robert Wood and Lou Nonini of the U.S. Bureau of Mines, Denver, visited with Industrial Minerals and Metals staff to obtain information on the geology, mineral resources, and mineral industries in and near the proposed Lake Calumet site for a new Chicago area airport. Their interest included the availability of materials required for construction and information bearing on resources that may become inaccessible if the project is carried forward. They were given or directed to information related to both developed and potential sources of crushed stone, sand and gravel, and clay and mineral-related manufacturing.

Impact of Mineral Resources on Future Use of Chanute Field, Masters, Mikulic, Hughes, Baxter Staff of the ISGS Industrial Mineral and Metals Section conferred with representatives of the Chicago and Boston offices of the federal General Services Administration (GSA) concerning possible impact of mineral resources on plans for disposal of Chanute Field properties.

Presentations to the Egyptian Council of Boy Scouts of America: Southern Illinois Fluorite (Occurrences, Geology, Exploration, Mining, and Uses), Baxter The ISGS was requested to provide and staff an information booth on fluorite at an encampment at Little Grassy Lake near Carbondale. About 200 scouts and an equal number of parents were in attendance. The presentations, with appropriate props, included (1) the chemical and physical characteristics of the mineral

fluorite (CaF_2); (2) the mode of occurrence of fluorite and accompanying minerals in the southern Illinois fluorspar deposits; (3) exploration methods (mapping, core drilling) and tools employed; (4) mining methods and personal safety equipment; and (5) uses.

MINERAL ECONOMICS

The responsibilities of the section expanded in the 1991-1992 reporting period to include aspects of strategic planning for the Illinois State Geological Survey. The year's emphasis was on energy.

Several studies examined the long term future of the coal and oil industries, including energy policies that are influenced by the events in worldwide oil markets. One project was dedicated to the study of which factors determined the oil prices in the past 20 years. Results indicated that domestic supply side factors are more significant in oil price determination than the influence of the OPEC. A second study concluded that coal prices are not significantly influenced by oil prices, and a third analysis indicated that the future of high sulfur coal requires a comprehensive economic approach rather than a narrow focus on problems such as sulfur removal alone. Recognition of the root causes of problems faced by the mineral industry is essential for the development of a sound long term strategy.

Benefit-Cost Analysis

Benefits and Costs of Geologic Mapping Programs in Illinois: Case Study of Boone and Winnebago Counties and Its Statewide Applicability, Bhagwat, Berg This study was conducted to meet the requirements of an Illinois Senate resolution on geologic mapping. Few of the benefits derived by society from the use of geologic maps have been systematically monitored in the past, although all users attest to the usefulness of mapping. Based on established principles of benefit/cost analysis, the study derives its conclusions from quantification of a single benefit accrued from avoiding the costs of cleaning up contaminated groundwater and/or contaminated sites. The results show that the benefits outweigh costs by as much as 27 times for the two counties studied and at least three times for the entire state. This study was published as ISGS Circular 549 and as a condensed article in *Environmental Geology and Water Sciences*.

Minerals Policy Analysis

Is Coal Price Linked to Oil Prices? Analysis of U.S. Fossil Fuel Prices in 1971-1988, Bhagwat The expected factors of influence on coal prices were modeled and the relationships statistically investigated. Results indicated that coal prices were mostly influenced by supply side factors such as interest rates, mine productivity, and growth of low cost coal mining in the western states. Prices were not influenced by changing coal demand nor the radical swings in world oil prices. The findings should be useful in future energy policy formulations. This work appears in *Proceedings of the 13th Annual North American Conference of the International Association for Energy Economics* (November 1991).

Economics of Utilization of High Sulfur Coal Resources—An Integrated Market Approach, Bhagwat The remedies designed to secure the future of high sulfur coals in the past targeted the task of removing the sulfur rather than the economic challenge of doing so at a competitive cost. The paper proposes an integrated market approach that will encompass all cost elements from mining to pollution control and waste disposal. Remedies must be designed to fit the specific characteristics of the coal, and policy decisions must be made on the basis of "total" cost competitiveness. Such an approach would improve the market for high sulfur coals. Some elements of this comprehensive approach have been visible in recent steps taken in Illinois. This paper was presented at the 121st Annual Meeting of the Society for Mining, Metallurgy and Exploration (SME) in Arizona in February 1992.

What Really Influenced the Crude Oil Prices in the 1971-1990 Period? Bhagwat A widespread perception is that crude oil prices are determined by the OPEC at will. Whether or not the OPEC is a cartel is not an issue to be left to the theoreticians because it determines the energy policies at all levels of government and industry in the United States. Many have studied this issue by applying the cartel criteria to OPEC and the oil prices. This study differs from most others in that it models factors from both the demand side and the supply side of the oil business. Statistical correlations over a 20-year period allow the effects of some factors to manifest themselves. The results indicate that oil prices may have been mainly influenced by supply side factors such as the cost of finding new oil deposits. The study affirms the role of dominant oil producers such as Saudi Arabia but assigns it a smaller role in price determination than the cost of finding new oil. The results also indicate that oil prices tend to self-regulate by affecting the demand and efficiency of energy use. The study results are significant for energy policy as they indicate that domestic policies to lower the finding costs could go a long way in oil price determination. This paper was presented at an IGT Conference on Modeling in June 1992.

Why High-Surface-Area Hydrated Lime Is Important for Illinois, Bhagwat Recent sulfur removal tests with the high-surface-area hydrated lime (HSAHL) indicate that dry sorbent injection (DSI) methods using HSAHL could achieve results comparable to those of traditional wet scrubbers. In the short run, HSAHL in DSI could enable many smaller electric utilities to comply with the mandates of the 1990 amendments to the Clean Air Act, if they act in time. In the long term, however, HSAHL must and potentially could compete with the efficient wet scrubbers, if the preliminary results are confirmed on commercial-scale experiments and the economic outcome is acceptable. Funding of the HSAHL project must take this long term view for the best returns on research investment. This reasoning was summarized in a paper submitted in March 1992 to the Illinois Department of Commerce and Community Affairs (DCCA) to support continued funding.

Disposal and Utilization of Coal Combustion Residues, Bhagwat, Dreher, Ehrlinger, Hughes, Roy Funding of \$46,500 was received for the Program Development Phase. A literature survey is being conducted to identify required areas of research that will form the basis of future requests for proposals under the program. This cooperative study with Southern Illinois University at Carbondale is divided into five categories: characterization, utilization, disposal, environmental impact, and socio-economic perspectives. Draft reports were submitted to the program director in May and July 1992.

Engineering Cost Analysis

An Economic Evaluation of Conceptual Commercial Scale Coal Desulfurization Plants: Ethanol and Carbon Monoxide-Ethanol Processes, Goheen, Joshi, Bhagwat The previous economic study of the three-step desulfurization process was revised. An additional study of the one-step process was also conducted. The studies were based on laboratory results, which have yet to be confirmed with extensive experimentation. The results of the study indicated that the one-step process, if technologically successful, has better a chance of succeeding economically than the three-step process. Breakeven product prices were estimated to be \$35 per ton for the one-step process and \$55 per ton for the three-step process. The final contract report to DCCA was submitted in August 1991.

Technology Transfer and Information Services Directory of Illinois Mineral Producers, 1991-1992, Samson, Masters The directory was completely revised from the previous issue (ISGS Illinois Mineral Notes 103). It provides quick reference to Illinois mineral producers and mineral processors by listing company names, addresses, phone numbers, and names and locations of pits, mines, and quarries. The directory is cross referenced with separate listings by county, company name, commodity (from barite to zinc).

Illinois Mineral Industry In 1989 and Review of Preliminary Mineral Production for 1990, Samson The mineral industries of Illinois mined, processed, and manufactured mineral-related products worth about \$2.85 billion in 1989 (ISGS Illinois Minerals 108). Mining accounted for nearly 90% of the total. The industry employed 120,500 persons, an increase of 3,500 from the previous year. Although jobs in mining declined, the increased employment in processing and manufacturing more than compensated for the losses. The income and sales taxes generated by mineral industry activities and their multiplier effects are significant.

Role of Industrial Minerals in the U.S. Economy, Bhagwat The chapter, "The Role of Industrial Minerals in the U.S. Economy," was contributed to the sixth edition of the book, *Industrial Minerals and Rocks*, to be published by the Society for Mining, Metallurgy, and Exploration (SME). Most industrial minerals are neither fuels nor metals, but they are fundamental to the

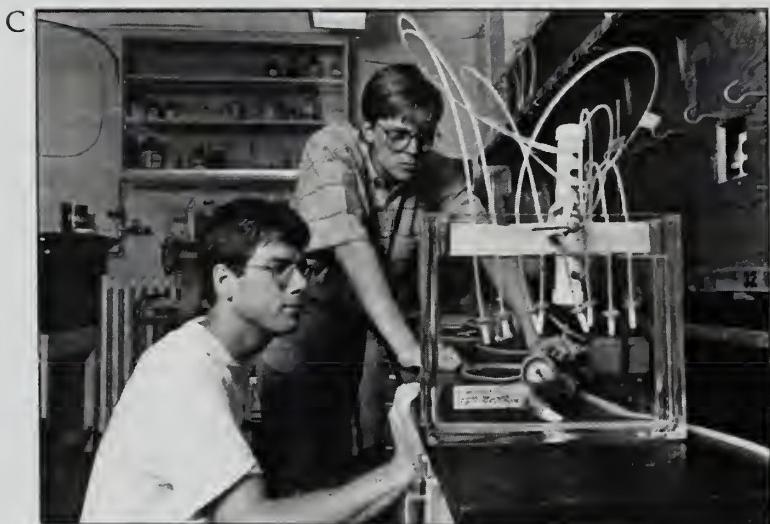
economies of modern, high technology societies. Although industrial minerals constitute less than 5% of the Gross Domestic Product, they make the remaining 95% of economic activities possible. As the basis of the nation's infrastructure as well as the housing and industrial sectors, industrial minerals claim high priority in the nation's policies. In contrast to the U.S. dependency on imports of crude oil and many metals, the nation produces most of its industrial minerals. This self-sufficiency contributes to economic stability.

Review of Coal Supply Prospects in the Asia/Pacific Region by Guy Doyle (International Energy Agency, 1990), Bhagwat The book was reviewed for *Energy Sources*, an international, interdisciplinary journal of

science and technology. In his book, Doyle summarizes the availability of coal for exports from the countries of the Asia-Pacific region. He takes into account the transport facilities as well as government policies supporting or hindering such exports.

Workshop: "Working to Ensure the Availability of Construction Materials: Demand, Resources, Land Use Planning, Environment, Economics," Bhagwat The paper, "Economics of Industrial Rocks and Minerals in Construction," was presented at a workshop cosponsored by the U.S. Geological Survey and the U.S. Bureau of Mines and held in St. Louis in September 1991. Dr. Bhagwat also chaired the panel discussion, "Factors Affecting the Cost of Industrial Minerals."

(A) Dan J. Van Roosendaal, engineering geologist, describes core retrieved from a borehole near Rend Lake for a mine subsidence project of the U. S. Bureau of Mines. (B) Christopher J. Stohr, engineering geologist and remote sensing coordinator, conducts a field investigation for an airborne, thermal infrared study of water infiltration through landfill covers. (C) Donald A. Keefer (right), hydrogeologist, and Damon Garner, a graduate student, test the suitability of field instruments for a groundwater protection project to measure pesticide movement. (D) Phillip R. Orozco (right), hydrogeologist, and his assistant measure the diameter of a borehole in Champaign County.



ENVIRONMENTAL GEOLOGY AND GEOCHEMISTRY

State policy decisions and actions during 1991-1992 in the area of environmental geology and geochemistry centered around land transfers, contamination problems, natural and manmade hazards, and concerns about sensitive areas such as wetlands and the Lake Michigan coast. Appropriate responses require access to comprehensive geological and geochemical databases. Consequently, current efforts are being directed toward building and maintaining the databases in coordination with environmental, contract-supported investigations.

The Critical Trends Assessment Project is designed to provide overview and direction to meet future needs. Current impact studies with the Illinois Department of Transportation and the Lands Unsuitable for Mining Project allow us to collect a broad spectrum of information throughout the state. Data from these and other studies, supplemented by current field investigations, support ISGS efforts to assist county planners in siting facilities such as landfills as well as to build a stronger database.

Geochemical and hydrogeological research address the issues of past and future contamination of groundwater and migration of contaminants in geologic materials. ISGS geochemists and hydrogeologists design and model site investigations, as well as interpret monitored laboratory and on-site information. ISGS researchers are nationally recognized for their valuable contributions to the study of contaminant transport. They are also gaining a reputation for their efforts to protect, restore, and construct wetlands.

The Environmental Geology and Geochemistry Branch responded to the environmental concerns of Illinois citizens through testimony, reports, publications, and other forms of information transfer. By necessity, response was timely—whether it was to a hearing officer on the proposed low-level radioactive waste facility near Martinsville, to engineering consultants who called for geologic data when the freight tunnels under Chicago flooded, or to emergency services staff preparing an earthquake risk map for exercises conducted in southern Illinois. Success depends upon maintaining a top-notch research group supported by a current and complete database.

ENVIRONMENTAL STUDIES AND ASSESSMENT

The Environmental Assessment Program responds to regional, county, and community needs for geologic information by providing information on the character and capacity of geologic materials to support specific uses of the land. Staff collect new data, correlate previous data and findings, and develop interpretations useful to federal, state, local agencies, industry and the public for land use decisions. The dynamic nature of society's uses of the land requires ongoing evaluation through environmental impact studies, facility location screenings, and land use analyses, so that informed decisions on environmental management

can be made. During the past year, the ISGS and agencies throughout Illinois began an ambitious effort to evaluate the overall environmental setting of the entire state. Review of past environmental changes and impacts will be integrated with projection of these critical trends into the future.

Critical Trends Analysis

Critical Trends Assessment Project *Schneider, McKay, L. Smith, Cahill, Bannon, C. Treworgy, O'Connor, Farrell, Witzany* In 1991, the Illinois Department of Energy and Natural Resources (ENR) was asked by the Governor's office to develop a program to assess the state of the environment in Illinois. The Critical Trends Assessment Project (CTAP) will assess environmental trends and conditions, illustrate the trends and conditions, and provide a basis for environmental management. The assessment will be based on a source/agent/receptor flow model. The Illinois Geographic Information System (GIS) will be the primary tool for the assembly, integration, and interpretation of data. The goal is to advance environmental and natural resource planning and management in Illinois by integrating science with public policy through publication of a biennial report, "State of the State's Environment," and development of an integrated, statewide environmental database.

During Phase I of CTAP, which began in the fall of 1991, focus has been on characterization and definition of potential sources, agents, and activities associated with sources and receptors. The scope of work was designed to complete tasks necessary for the first phase of a multiyear effort. Two major goals were met:

1. Elements necessary to conduct a critical trends assessment and/or comparative risk analysis for the State of Illinois using GIS technology were investigated and developed. This required a search of scientific literature on such assessments and methods, an inventory and evaluation of existing databases and techniques, and the identification of potentially useful but missing databases and techniques. Among the products delivered was a partly annotated bibliography containing 1,062 entries covering 23 topical areas.

2. A comprehensive work plan for Phase II of the study was completed and submitted.

Phase II was implemented during June 1992; work on the assembly and automation of data for use in the CTAP is underway. Analysis of the data sets will begin as the data are compiled. The report is scheduled for completion in the fall of 1993.

Special Siting Studies

Value-Added Effort to Conclude the Superconducting Super Collider (SSC) Program, *Schneider, others* Review and production of publications developed during the SSC investigation continued as anticipated during the past year and included the following:

- *Illinois Geographic Information System: Applications to Environmental Management*, *Krumb, Erdmann, Joselyn (INHS)* This report, published as ISGS

Environmental Geology 140, was the final product for SSC wrap-up task 110. Directed toward a nontechnical audience, the publication describes the Illinois Geographic Information System (IGIS) and provides three in-depth examples of its use at the state, county, and local levels.

- *Slope Percent Map of Kane County, Schneider, Read, Barclift* Released as Open File Series 1990-2e, this digital product is derived from USDA Soil Conservation Service maps and shows the distribution of slope percent throughout Kane County.

Environmental Impact Studies

Environmental Property Assessments for the Illinois Department of Transportation, Schneider, Bauer, Erdmann, Bannon, Trask, Berggren, Van Roosendaal, Miner, Read, Farrell, O'Connor, Swick, Kientop, Wampfler, Adomaitis, Hart, Geiger, Denny, Carlisle The statewide environmental property assessment program for IDOT entered into its fourth year of work during the last quarter of the fiscal year. During the past year, 100 reports representing 275 miles of state highway projects were completed. Interpretation of data by ISGS and IDOT staff, using criteria developed jointly, resulted in establishing a high risk assessment for 28 of the projects and moderate risk for 18. All others were assessed as having low or no risk to the proposed highway construction.

High and moderate assessments reflect environmental conditions that may affect project completion or seriously impede timely progress. Prime environmental hazards are previously unknown, leaking, underground storage tanks. Depending upon the geology where these tanks are located, the impact on construction and potential liability of the state for cleanup can be a major concern. A comprehensive, digital database reflecting information gathered by project geologists and historical researchers is being established, and data relating to the methods of producing such reports are being compiled.

Illinois Lands Unsuitable For Mining Program, Pool, Taylor, McKay, L. Smith, Stiff LUMP is funded by the U.S. Office of Surface Mining (OSM) through the Illinois Department of Mines and Minerals (IDMM). Through the program, the Illinois Department of Energy and Natural Resources (ENR) assists the IDMM with their mine permit review program and maintains data files that support LUMP. During the past year, the program has been scaled back in response to reduced funding by OSM.

The ISGS, directing project staff in other ENR divisions, continues to develop a GIS computer database of coal mine permit information for surface and underground mines and carbon recovery operations in Illinois. The database consists of digitized map and other data for more than 200 mine permits. The objectives for this fiscal year include the entry of information on affected acreage (areas modified by mining) and bond release (areas for which the company posts a substantial bond to ensure appropriate reclamation). A menu-driven computer interface for using the

database was refined and a manual written to assist users with menu applications.

GEOLOGY FOR PLANNING

County-level geologic and hydrogeologic investigations focus on identifying resources and describing properties of materials. With this information, local officials can make reasonable decisions concerning environmental and economic management of their communities. Although studies vary in scope, depending on the needs of the county, they provide information at a scale most useful for county, land use planners.

County Regional Studies

Resource-Based, Land Use Planning in Kane County, Trask, Erdmann, Schneider, L. Smith, T. Larson Computer analysis of data from well and drill logs, along with field observations, were completed for the project in the spring of 1992. A study area encompassing eight townships in the western and northwestern sections of the county has been analyzed, using GIS techniques, to produce a three-dimensional model of geologic materials above bedrock. Combined with maps showing properties of un lithified deposits and maps of geologic materials at various depths below ground surface, this model will help land use planners in Kane County to decide on siting public works projects. Interpretive maps and a comprehensive report are being prepared.

LAKE MICHIGAN COAST AND BASIN

Illinois State Geological Survey staff continue their investigations along the Illinois shore of Lake Michigan. This effort provides detailed information on the character of coastline features and the interaction of geologic processes and manmade structures. Studies include collaborative work with the U.S. Geological Survey (USGS) and coastal researchers from Northeastern Illinois University. Research activities have been supported mainly through an agreement with the USGS. Additional funding has also been obtained from the Federal Emergency Management Agency (FEMA), the Illinois Department of Conservation (IDOC), and the Illinois Department of Transportation (IDOT).

An overview of continuing investigations of southern Lake Michigan is providing new insight on the past and present interpretation of these coastal areas. The impact of lake dynamics on beaches, bluffs, coastal-defense structures, and other coastal development of one of the most populated and developed shorelines of the Great Lakes makes it imperative that the ISGS maintain its coastal research program. Not only is the research important for informing all levels of the public and private sectors, but also for implementing policies for coastal development and mitigation of the effects of erosion.

Coastal Erosion Studies

Lake County Pilot Erosion Rate Data Study, Erdmann, Stohr, Chrzaszowski, Terpstra, Read, Kraus Pending revisions to the National Flood Insurance Program will

require FEMA to coordinate a national program to map historical changes in the shorelines along the U.S. seacoasts and Great Lakes coasts. A FEMA-supported pilot study to evaluate methods and data sources is being conducted along the Lake Michigan coast of Lake County. Digital databases are being created from historical maps and aerial photography spanning 115 years of coastal change.

Coastal Monitoring of the Sedimentary Impact of Shore Structures

North Point Marina Beach and Nearshore Monitoring, Chrzastowski, Terpstra Annual monitoring of coastal geomorphic changes in the vicinity of North Point Marina has been underway since 1988 as part of the Southern Lake Michigan Coastal Erosion Study sponsored by the U.S. Geological Survey (USGS). Monitoring of changes in beach and nearshore geomorphology is assisting the Illinois Department of Conservation to manage local coasts. Digital map data from 1988 to early 1992 were prepared for a CD-ROM to be created by the USGS. Included are maps showing annual bathymetry, lake bottom change, and shoreline change.

Coastal Monitoring at Forest Park Beach, Chrzastowski, Trask In August 1991, the first year of a 5-year monitoring program began at this beach in Lake Forest. Through an agreement with the Illinois Department of Transportation, Division of Water Resources (IDOT-DWR), the ISGS is responsible for quality assurance/quality control in the monitoring surveys conducted by Lake Forest. Data processing and comparisons were conducted in fall of 1991. In April, the first-year report was completed, reviewing the 1991 coastal monitoring by the city of Lake Forest at the Forest Park Beach project. Also reported were discoveries of (1) an accumulation of fine sand in the northern beach area, and (2) a mechanism for littoral sediment bypass around the engineered structures. The ISGS will continue to assist the IDOT-DWR in the monitoring program during the next fiscal year.

Coastal Sediment Mapping

Littoral Zone Habitat Classification and Mapping of Illinois Lake Michigan Coastal Areas, Fucciolo, Miner This project, supported by the Illinois Department of Conservation, began in 1990 to assist IDOC's Division of Fisheries in management of the State's Lake Michigan fishery. Because fish spawning, feeding, and migration are related to lake bottom materials and water depths, these parameters were mapped in selected areas of Lake Michigan. Funding is provided by the U.S. Fish and Wildlife Service and administered by IDOC. In the summer of 1991, the second year of a 2-year mapping program, researchers continued to map and produce a digital database of bottom sediment distribution in select harbors and nearshore areas along the Illinois lakeshore.

During the 2-year span of the project, bottom materials were sampled and mapped in all of Chicago's small boat harbors and in the vicinity of north Lincoln Park and the Edgewater District. Lacustrine sediments

were classified into seven categories based on the basis of grain size and percentage of composition. Color-coded maps showing the areal extent of lacustrine sediments and glacial till were prepared. Bathymetric data, contoured in 1-foot intervals, were added.

Maps have been completed for Montrose, Belmont, Diversey, Monroe, Burnham Park, 59th Street, and Jackson Park Harbors and the nearshore regions of north Lincoln Park and Edgewater. Preparation of the final contract report including the production of sediment sample location maps, sediment sample descriptions, and bathymetric profile location maps is nearly complete.

Lake History Studies

Investigations at the Olson Site, Chrzastowski In May 1992, researchers drilled into a buried river channel on the floor of southern Lake Michigan near the site of the 8,300-year-old tree stumps first discovered in 1989. A 6-meter core was recovered by means of a hydraulic coring method specially designed for this project. Core analysis will provide new data on the history of lake levels and the postglacial rise in lake levels.

Environmental Geochemistry

PCBs in Waukegan Harbor Sediments, Risatti, Salmon ISGS scientists have been involved for several years in studying the distribution and fate of PCBs in the sediments of Waukegan Harbor. The initial study was funded by the Hazardous Waste Research and Information Center. Investigation of the distribution and fate of PCB congeners in sediments are being determined to evaluate the long term fate of PCB mixtures in aqueous sediments of Waukegan Harbor. Twenty-seven sediment samples have been extracted and fractionated; they await analysis by gas chromatography.

WETLANDS, RIVERS, INTERIOR LAKES

National concern over the jurisdictional wetlands question is mirrored in Illinois by increased demand, particularly by state agencies, for wetlands information. Investigations of the geologic processes important to wetland preservation, restoration, and creation have received increased attention during this report period. The demand for information outstrips our ability to study and generate data on these complex systems. Efforts include supplying basic hydrogeologic and geomorphic information for mitigation plans, feasibility studies, and construction impacts on wetland environments.

The agreement between the IDOT and the ISGS during the last report period continues. Other wetland and riverine systems, such as the Des Plaines River and Volo Bog, continue to be studied at the ISGS and affiliated agencies.

Wetlands Investigations

Chemistry and Origin of Groundwater in Volo Bog, Lake County, Risatti (ISGS); Cooper (Purdue University) Objectives of this project are to determine the sources of groundwater flowing into the bog and to monitor

changes in the groundwater chemistry. Water samples collected in January and May were analyzed for alkalinity, anions, and cations. Temperature and pH were determined in situ. Wells will be sampled through summer of 1993, and the water chemistry will be monitored. These data and the availability of the wells to monitor water quality will be especially important as the surrounding rural area is now being rapidly developed. The urbanization will also increase the demand for groundwater supplies.

Grand Calumet River Sediment Study, Cahill (ISGS); Unger (Inland Steel); Hickey (HNTB) The sediments of the West Branch of the Grand Calumet River are highly polluted and the area is being considered for environmental restoration and development. Decisions regarding dredging and/or remediation of the area require reliable estimates of the quantity and quality of the sediments that are in place. Sedimentation rates were determined at 11 locations using the cesium-137 technique. High sedimentation rates were confined to one region of the river (>1 cm/y), whereas most of the river showed low sediment rates (<0.1 cm/y). Concentrations of organic carbon, zinc, and tin were determined in 120 sediment subsamples. Twenty-four additional elements were determined in 46 sub-samples. Very high concentrations of copper (1,000 ppm), zinc (9,000 ppm), cadmium (84 ppm), tin (1,600 ppm) and lead (1,885 ppm) were found. Sediments with high metal contents were generally confined to the downstream locations in Hammond, Indiana. A manuscript reporting the cesium-137 results was submitted to the *Journal of Great Lakes Research*.

Des Plaines River Wetlands Demonstration Project, Miller As a part of the results of continued monitoring at this wetlands project, analysis of water table elevations from monitoring wells shows that operation of the experimental wetland areas has locally affected water table elevation. During the dry spring and summer of 1991, water table readings were as low as levels measured during the 1988 drought. Around the experimental wetland, the levels of wells that continued to receive pumped water did not show this decrease up to the time that monitoring was discontinued. Final groundwater monitoring was completed in September of 1991. Analysis to evaluate channel stability continues on the river cross section data collected during July 1990 and 1991. Surface water monitoring is to continue through December of 1992.

Wetlands Investigations for the Illinois Department of Transportation, Schneider, others This program has just completed its first year and is designed to assist IDOT with mitigation, delineation, and research on wetland issues. Major site investigations were either completed or begun in the northern half of the state.

• **Black Partridge Forest Preserve, Hensel, K. Cartwright, Hansel, Barnhardt** This study considered probable effects on a spring-fed wetland as a result of highway construction over a recharge area for the spring. A final report submitted in May 1992 indicated

that discharge at the spring may be reduced by 8% to 24% after highway construction. The amount of reduction depends upon highway alignment and drainage; the most likely reduction is 8% to 11%.

• **Schaumburg Commuter Rail Station Cahill, Miller, Risatti** In 1981, before a commuter rail station, parking lot, and access road were constructed, soil samples were collected from an adjacent wetland. The samples were preserved, then recently analyzed to determine inorganic and organic components as well as previous sedimentation rates. Sedimentation rates ranged from 0.4 to 1 cm/y. Concentrations of metals were at "background" levels, whereas organic compounds detected at one location indicated a probable petrochemical spill or disposal area. The site was revisited in March 1992 and water and soil samples taken for comparative analyses. Analyses of water samples indicate that concentrations of sodium and chloride had increased. One probable cause for the increase is runoff contamination from the adjacent parking lot. Sedimentation rates do not, however, appear to have increased. Data continue to be collected, compared, and interpreted.

• **Elgin-O'Hare Expressway Corridor, Miller, Cahill** This major highway construction project requires IDOT to provide a wetland mitigation strategy that includes construction and restoration of wetlands in the area to meet state and federal regulations. For the IDOT mitigation plan, the ISGS will work together with the Illinois Natural History Survey (INHS) to establish the framework and baseline conditions as well as biological and physical parameters for the creation of wetlands. Development of the wetlands and adjacent sedge meadows will be monitored by both the ISGS and INHS. Periodic recommendations will be made to IDOT so that the stated goals can be met by the end of an extended monitoring period.

GROUNDWATER PROTECTION

The ISGS Groundwater Protection Program is designed primarily to meet the mandates of the Illinois Groundwater Protection Act. Conducting statewide assessments by locating and mapping aquifers, determining water quality, and investigating the impact of pesticides on groundwater have been conducted at the local or municipal, county, and regional or state levels. Focus has been to determine the geological framework of aquifer systems, evaluate how groundwater interacts with earth materials, and finally develop groundwater contamination potential and land use planning maps. Although each step of the process is conducted at an appropriate scale, the overall objective is to assess and map at the 1:24,000 scale (1 inch on the map represents 2,000 feet on the ground). Geologic information at this scale is most useful for land use decisions.

Geologic Mapping for Groundwater Protection McHenry County, Curry, Berg, Barnhardt, Dey, Panno, Greenpool (ISGS); Rehfeldt, Karny (ISWS) The ISGS and ISWS are cooperating in a groundwater protection mapping project in McHenry County. Utilizing funds

provided by the McHenry County Board of Health, ENR's Aquifer Assessment Program, and the Hazardous Waste Research Fund, the ISGS and ISWS are delineating aquifers and determining aquifer and confining bed properties. This assessment is being conducted at a scale of 1:24,000. At least two cross sections per quadrangle have been completed for about 45% of the quadrangles. Water well locations have been verified for about 90% of the quadrangles. A surficial geologic map has also been prepared and is currently undergoing revision. This is the first year of a 3-year project.

Geologic Aspects of a Groundwater Protection Needs Assessment in Woodstock, Illinois, Berg, Mushrush

Woodstock was selected by the ISGS and ISWS, with the cooperation of the Illinois Department of Environmental Protection Agency (IEPA), as the locus of a groundwater protection needs assessment. Work on this project involves detailed geologic and hydrologic mapping of the entire Woodstock 7.5-Minute Topographic Quadrangle.

Researchers will define areas of potential contamination (vulnerability of aquifers to contamination) and evaluate characteristics of both aquifer and nonaquifer materials. Four cross sections (north-south, east-west, southwest-northeast, and northwest-southeast), isopach maps of each of four drift aquifers, and a stack-unit map to a depth of 100 feet were digitized and will be included in the final report. A method will also be developed for incorporating these data into an easily retrievable database.

Contamination Potential Mapping for the Chicago 4° x 6° Quadrangle, Berg (ISGS); Soller (USGS) The ISGS is cooperating with the USGS to produce a contamination potential map for parts of five states surrounding the southern basin of Lake Michigan. The map is based upon USGS data on drift thickness, nature of the surficial materials, bedrock lithology, and presence or absence of buried aquifers. The primary contribution of the ISGS was development of the contamination potential rating schemes. A companion text will be printed on the map sheet. The map, now in peer review, will be published in the USGS I-Map series.

Model for the Assessment of Aquifer Contamination Potential Based on Regional Geologic Framework, Soller (USGS); Berg (ISGS) A model was developed to identify aquifers and rank sequences of geologic materials by their relative potential for transmitting water and contamination from land surface. The model can be used to assess the potential for contamination of aquifers by surface activities. Using broad, easily obtainable geologic information, the model is intended to be a general tool to assess aquifer sensitivity to contamination. It cannot be used to evaluate local, specific sites; however, it can be used to prioritize local areas where contamination is suspected. Research results were published in the May-June 1992 volume of *Environmental Geology and the Water Sciences*.

Pesticides in Groundwater

Pilot Study—Agricultural Chemicals in Rural, Private Water Wells, E. Mehnert, Barnhardt, Dey, Greenpool The ISGS and ISWS completed this pilot study conducted in cooperation with the Illinois Department of Agriculture (IDOA) to field test and evaluate various components of the experimental design of a proposed statewide survey, as described in ISGS/ISWS Cooperative Groundwater Report 11. The pilot study provides a preliminary assessment of the occurrences of agricultural chemicals in rural, private wells in five study areas representing four hydrogeologic settings and two well types. The results are described in ISGS/ISWS Cooperative Groundwater Report 14. Water samples from 240 rural private wells were sampled over a 1-year period and analyzed for nitrate and 38 pesticides. Nitrate was detected in 42 of the 240 wells sampled; one or more pesticides were detected in 24 of the 240 wells samples. Overall, one or more agricultural chemicals were detected in 23% of the samples (55 of 240) of the wells sampled.

Although these results indicated that agricultural chemicals leach to groundwater, their occurrence is not uniform across the five study areas and is generally controlled by well type (drilled or driven versus dug or bored) and depth to uppermost aquifer material. A report describing the hydrologic and geologic characteristics of the five study areas, as well as the methods of characterization, will be published soon as ISWS/ISGS Cooperative Groundwater Report 15, *Characterization of the Study Areas for the Pilot Study: Agricultural Chemicals in Rural, Private Wells in Illinois*.

Procedures and Guidelines for Addressing Pesticide Contamination at Agrichemical Facilities in Illinois, McKenna, Roy, Krapac, Barnhardt, Herzog, Risatti, E. Mehnert Under the direction of Dr. Roy, the ISGS continues to assist the IDOA in responding to the 1990 amendments to the Illinois Pesticide Act. The IDOA is required to develop guidelines and recommendations for the remediation of pesticide-contaminated soil and groundwater at the 1,300 agrichemical facilities in Illinois.

During the report period, 17 of 19 site assessments were completed; data were received on the concentrations and distribution of pesticides with depth, as determined from four core samples collected at each site. The results of the analyses are currently under study, which will include an evaluation of the site conditions and the operational conditions at each site. Preliminary results indicate that the frequency of contamination detected does not seem to correlate with the age or size of the site. Moreover, pesticides have been most frequently detected in the gravel layers at the surface of each site. The most commonly detected pesticides were trifluralin, metolachlor, and atrazine.

From a list of all agrichemical facilities in Illinois, two sites were randomly selected, based on their location with respect to the depth of the nearest aquifer. The two sites were drilled by a private contractor under the supervision of ISGS geologists. Two hundred 15-foot-deep holes were drilled at the two sites. About

700 soil samples were collected for nitrate and selected pesticide analyses. Four groundwater monitoring wells were installed at each site, and additional wells will be installed, based on the results of the chemical analysis.

Pesticides are designed to be used in the environment, so defining "pesticide contamination" is difficult. A flexible definition of soil-pesticide contamination has been proposed whereby the environmental fate of a pesticide in the soil-water system is used to assess remedial action. If a pesticide is immobile, for example, in situ treatment or excavation may not be necessary. To test this operational definition, we are attempting to assess the fate of pesticides detected at the two sites. Slug tests are being conducted at each well to evaluate the movement of groundwater beneath each site. The permeability of gravel fill and nonfill areas at each site is also being measured to evaluate the vertical movement of infiltration near the surface. These measurements will be used in solute-transport modeling studies to estimate how the chemicals will move.

Two draft reports have been submitted to the IDOA and are currently being revised and expanded.

Groundwater Contributions to Atrazine Loadings in Streams, McKenna, Roy, Krapac, Risatti, S.F.J. Chou, E. Mehnert, Kirvelaitis The purpose of this field and laboratory study, now under the direction of Dr. Roy, is to determine the environmental fate and movement of the pesticide atrazine and two primary degradation products, de-ethylatrazine (DEA) and deisopropylatrazine, in a small watershed in Champaign County. The subsurface movements of atrazine are being investigated to determine the primary pathway(s) by which it enters the Embarras River.

The general lack of conversion of atrazine to DEA, via biological degradation, suggests that the primary route of atrazine movement at the study area is by overland flow from the field into a tile drainage system, which in turn discharges into the river. There is little evidence that the atrazine infiltrating into the soil reaches the river. Solute-transport modeling will be conducted to better define the possible pathways of movement.

Laboratory studies are being conducted to determine the adsorption-desorption behavior of atrazine and DEA by subsurface materials collected at the site. The extent of atrazine adsorption by samples of glacial till and outwash collected at depth at the site was greater than expected. The adsorption of atrazine often correlates with the amount of organic carbon present in the soil; however, the adsorption of atrazine correlated with the pH of the low organic carbon materials. DEA may be more mobile than the parent atrazine. The apparent organic carbon-water partition coefficient (*K_{oc}*) of DEA is about 0.19 to 0.65 of that of atrazine. Like atrazine, there was an inverse relationship between DEA adsorption and pH. The adsorption of atrazine by the low organic-carbon materials was often hysteretic; once adsorbed it was not completely released in laboratory experiments. Similarly, DEA adsorption was somewhat hysteretic, but to a lesser extent than atrazine.

The biodegradation of atrazine under anaerobic conditions is also being studied. If atrazine biodegrades to DEA under conditions that simulate the study area, then the overland flow hypothesis will be supported. The first sequence of experiments is being conducted for 8 weeks. Trial tests indicated that the mean recovery of atrazine was 102%. Analyses are ongoing.

A first-year summary of this project was presented at the Second Annual Conference of the Illinois Groundwater Consortium in Springfield. An understanding of how pesticides enter surface water may lead to better management practices that will minimize surface-water contamination by agrichemicals.

Potential for Agricultural Chemical Contamination of Aquifers in Illinois, McKenna, Keefer In support of the State's Pesticide Management Plan developed by the IDOA, statewide geologic mapping of Illinois was used to identify regions with aquifers vulnerable to contamination by agricultural chemicals. A state map at a scale of 1:500,000 and maps for each county at a scale of 1:250,000 were prepared. Areas with intensive corn and soybean production and aquifer materials within 50 feet of ground surface are most vulnerable to contamination. In approximately 40% of rural Illinois, aquifers lie within 50 feet of ground surface. These shallow aquifers occur throughout Illinois but are most common in the northern and southern parts of the state and along the major river valleys. In about 60% of rural Illinois, the aquifers are more than 50 feet deep and apparently protected from pesticide contamination by the attenuation capacity of soils and thick sequences of fine-grained materials. Pesticide use, largely for corn and soybean production, is heaviest in areas of the state where aquifers are generally found to be least vulnerable to contamination.

Characterization of Unsaturated Water Flow and Water Table Behavior, Keefer Macropores in soil and other geologic materials have been identified in recent years as contributing to the preferential movement of water and agricultural chemicals into groundwater. Several methods qualitatively identify the importance of macropores for chemical transport; few studies have developed methods for quantitative measures of the hydrologic importance of these pores. This project is designed to develop and field-test methods for quantifying the occurrence of macropore flow in fine-grained, structured soils and other geologic materials.

Several field methods were identified and modified on the basis of an extensive literature review. The methods utilize tension infiltrometers, fluorescent dye tracer tests, tensiometers, and gypsum blocks. The tension infiltrometers will be used to measure the hydraulic conductivity of the soil and geologic materials at various degrees of saturation and various depths. These instruments will provide a quantitative measure of the importance of various pore sizes under increasingly unsaturated conditions. The fluorescent dye tests will be used to quantify the scale of variability of macropore flow, as observable in $1.5 \times 1.5 \times 1.0$ meter

blocks of soil. The tests are expected to produce results that can be correlated with the results from the tension infiltrometer tests. Tensiometers and gypsum blocks will be used to monitor the soil water energy status and soil moisture content, respectively. These instruments have been included in an effort to relate the observed preferential flow behavior to more commonly measured soil water properties.

Validation of Analytical Methods for Pesticides by an Inter-Laboratory Comparison, S.F.J. Chou, Roy The results and procedures of three projects funded by the Illinois Groundwater Consortium to study atrazine in soils and groundwater were compared through a round-robin analysis. Participants in the study, the ISGS and Southern Illinois University at Carbondale (SIU-C), exchanged and analyzed pesticide-containing soils and solutions. The goals of this effort were to determine whether the two laboratories produced comparable analytical results, and to assist all research groups in improving their analytical procedures. The preliminary results indicated that, in most cases, the percent recoveries of all of the analytes in soil and water spikes were within or near the tolerance range of 70% to 130%. An exception to this finding is that deisopropylatrazine concentrations determined in spiked samples by the ISGS were approximately 10% to 20% below the tolerance range, and some atrazine concentrations determined in spiked soils by SIU-C were more than 30% above the tolerance range.

The analysis of C-14 labeled stock solutions and water samples showed both laboratories achieved good agreement between concentrations measured by gas chromatography and liquid scintillation counting, with the exception that the concentration of atrazine in the SIU-C aqueous samples as determined by SIU-C under "wet burn" and "dry burn" conditions were significantly lower than those determined by the ISGS. However, the atrazine concentrations determined by SIU-C by using direct spiking of scintillation cocktails were comparable to the ISGS results. The Executive Committee of the Illinois Groundwater Consortium has requested that this work continue during 1992-1993.

Effect of Quaternary Ammonium Cation on Sorption and Leaching of Atrazine in Coarse Textured, Sandy Soils, S.F.J. Chou Pesticides applied to sandy soils are susceptible to leaching and likely to enter groundwater. A method to reduce pesticide movement in coarse, sandy soils was investigated by evaluating the effect of quaternary ammonium cationic (QAC) surfactants on sorption and leaching in sandy soils.

In preliminary studies, the results showed that benzylidimethyl-decylammonium chloride significantly increased the adsorption and reduced the leaching of atrazine in sandy soil. Four QACs, tetraethylammonium bromide, benzyltrimethyl-ammonium bromide, benzyltriethylammonium bromide, and benzylidimethyldecylammonium chloride are also under evaluation. One of the QACs showing the highest uptake of atrazine from solution will be selected for further soil column leaching studies. This study will provide

basic information for the possible use of QACs in coarse textured, sandy soils to reduce pesticide leaching into groundwater.

Remediation of Pesticide-Contaminated Soils by a White-Rot Fungus, S.F.J. Chou Recent studies have shown that a white-rot fungus, *Phanerochaete chrysosporium*, possesses an exceptional ability to degrade halogenated, aromatic pollutants and pesticides. Given the capability of the fungus to degrade a variety of organic pollutants to carbon dioxide, this organism may prove useful in the treatment of pesticide-contaminated soils. Currently, a preliminary study is being conducted to select the optimum conditions for fungal survival and degradation of selected pesticides in soils. The experience gained from this study will be applied to the treatment of pesticide-contaminated fill materials at selected agricultural facilities in Illinois. The investigation is a part of the 3-year project, Fate and Transport of Pesticides in Surficial Materials at Agricultural Facilities, supported by the Illinois Groundwater Consortium at SIU-C.

Solid-Phase Extraction for Determination of Acetanilides and Triazines in Soil Extracts, S.F.J. Chou Liquid-liquid extraction procedures used for pesticide determination in soil extract often require large volumes of samples and solvents; these procedures thus become cumbersome and tedious. Also, a cleanup step may be necessary after liquid-liquid extraction. In solid-phase extraction (SPE) procedures, pesticides are extracted by passing a large amount of sample through a column packed with adsorbent and eluted with an organic solvent. This technique recovers pesticides but eliminates most interferants and avoids the need for further extract cleanup. Preliminary results showed that good recoveries for alachlor, metolachlor, atrazine, and cyanazine were observed; 65% to 88% of spiked pesticides were recovered from the Catlin soil. The results of this study will be reported in a journal article.

Other Research Activities

Genesis of Shallow Saline Groundwater in Central-Southern Illinois Basin, Hwang, Anderson (UI-UC); Liu, Hackley, K. Cartwright (ISGS) This joint research involving the University's Department of Geology and the ISGS Isotope Geochemistry Laboratory was proposed by Hue-Hwa Hwang for her Ph.D. dissertation under the supervision of Professor Thomas Anderson. The project was designed to investigate the relationship of shallow saline groundwater to basin brine through the study of chemical and isotopic evolution of shallow saline groundwater in central southern Illinois. Through this research, a better understanding of the basin brine migration pattern and its hydrological implication for deep sedimentary basin environments may be achieved.

The project began in July 1991 and is expected to be complete in 2½ years. Fifty saline groundwater samples were collected and analyzed chemically and isotopically; 20 more samples will be collected in August. Interpretation and modeling have begun.

WASTE MANAGEMENT

Waste management issues have been at the forefront of environmental programs at the ISGS for more than 30 years. Primary objectives have been to technically assist agencies planning the management of wastes, and to evaluate sites proposed for the disposal of low-level radioactive, hazardous, and coal wastes. Technical assistance programs have (1) helped county government understand the complexities of geology so that they can make meaningful decisions for landfills, and (2) assisted the Illinois Department of Nuclear Safety and their subcontractors to interpret and evaluate candidate sites for low-level radioactive wastes. In addition, ISGS research on underground injection of wastes, use of environmental isotopes to study leachate and gas migration, and coal wastes all evaluate the movement of hazardous substances in groundwater. The research is designed to predict potential problems and problem areas before contamination occurs.

Landfill Monitoring

Application of Environmental Isotopes to Studying the Migration Pattern of Landfill Gases and Leachate, Hackley, Liu The Isotope Geochemistry Laboratory, under a contract with Waste Management Inc. of Illinois, has undertaken to determine which set of isotopic analyses will yield the most useful information for characterizing and tracing landfill gases and leachates. The analytical work involved with this project includes $\delta^{13}\text{C}$, $\delta^{14}\text{C}$, and tritium analysis of dissolved inorganic carbon (DIC) and methane; δD and $\delta^{18}\text{O}$ analysis of water, as well as gas chromatographic analysis of landfill gases. The project started in December 1991 and was targeted to be complete by March 1992; how-ever, expansion of the project set the completion date back to August 1992.

The results obtained from this project so far have shown that at the sites studied, tritium is a good indicator for monitoring migrational pathways for landfill leachate. The tritium concentration in the landfill leachates analysed was more than an order of magnitude higher than that in the uncontaminated shallow groundwater. Data also show that carbon-13 and deuterium are enriched in landfill leachate and therefore can also be used as indicators in studying leachate contamination. Two site reports have been prepared for Waste Management Inc. of Illinois. Preparation of a third report is currently underway.

Landfill Siting

Evaluation of Composting with Regard to the Breakdown of Pesticides, Cahill, Salmon (ISGS); Kovacic, Wilkinson (UI-UC) Municipal yard waste composting facilities are now common in Illinois, as a result of the banning of yard waste in landfills as of July 1990. In the "rush to compost," the environmental fate of the pesticides and metals in yard waste has not been properly evaluated. An article was published in the journal, *Environmental Science and Technology*, to alert designers of compost facilities to the potential for leaching of potentially hazardous constituents from yard waste and finished compost. To continue research

into this issue, a proposal was funded by the Office for Solid Waste Research to study the breakdown of selected pesticides on turf grass. The work began in January 1992 and involves the study of the fate of pesticides from controlled applications on test turf grass in greenhouse and field experiments.

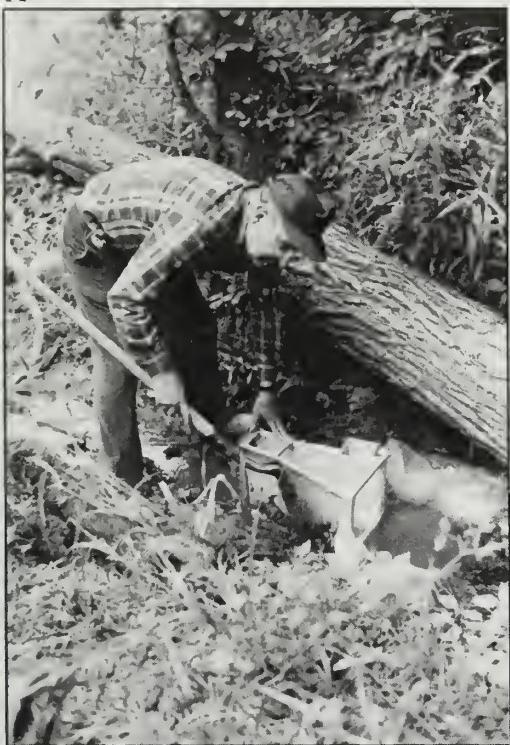
County GIS Screening for Landfill Siting, McKay, McLean, Abert, Riggs, Denhart, Junkins, Krumm This project, funded by the Illinois Department of Energy and Natural Resources (ENR) Office of Recycling and Waste Reduction (ORWR), is designed to assist county governments in landfill siting. Maps, graphics, and other data are prepared to help county officials make better informed decisions. The ISGS prepares maps to delineate features such as subsurface sand and gravel units that may be potential sources of groundwater. Protection of these resources is of primary concern to most counties siting landfills. Computer mapping techniques are used to compile data sets, analyze information, and prepare maps, cross sections, and other graphics. Recent efforts have focused on completing the Will County maps for publication by the ISGS and on beginning the mapping for McLean County.

Draft versions of Will County geologic maps at a scale of 1:100,000 include the General Surface Topography, Bedrock Topography, Thickness of Glacial Deposits and Consolidated Materials, and Sand and Gravel Isolith Maps. Also to be published are series of "depth slice" maps and "elevation slice" maps showing the distribution and thickness of coarse and fine grained materials from the ground surface to a depth of 200 feet. Project staff have also worked with the Will County Waste Services Director to develop landfill siting criteria; and they continue to develop landfill capability maps.

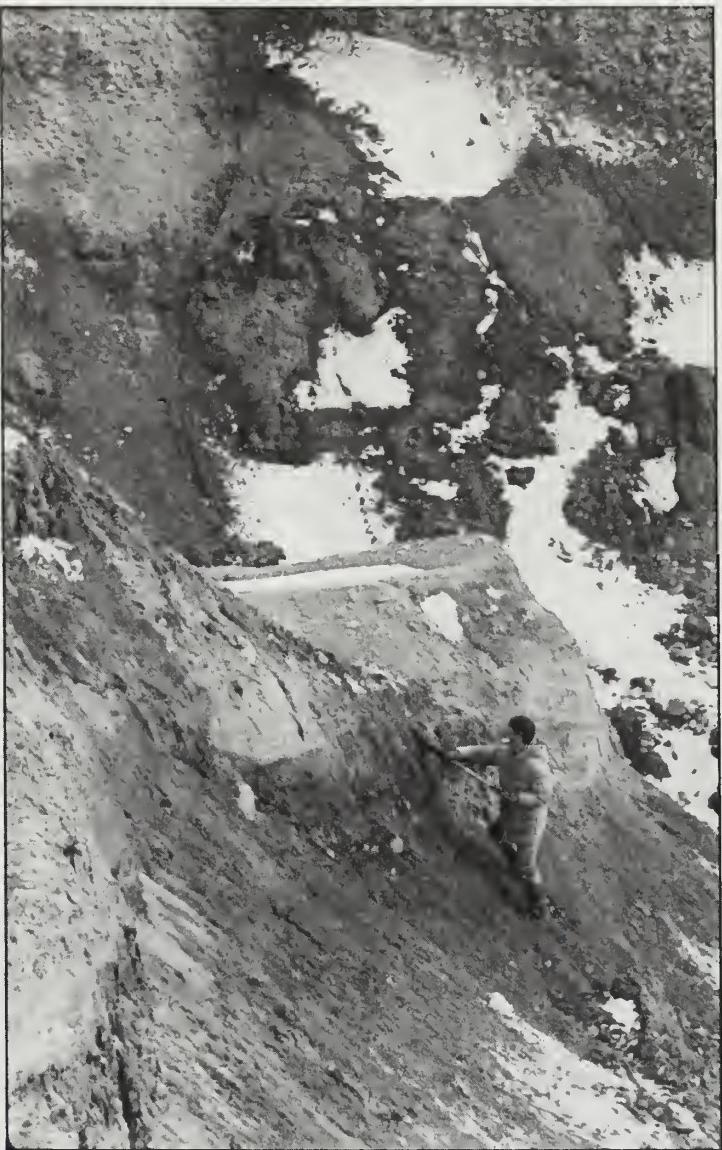
In other activities for McLean County, staff are cooperating with the USGS to create a digital map of the surface topography of McLean County; the USGS has provided the ISGS with scanned data for the thirty-three 7.5-minute quadrangles in McLean County. Project staff are also correcting the line work and attributing the data to USGS Digital Line Graph (DLG) standards. These data will be combined with a new bedrock topography map produced from well data and used to estimate the thickness of glacial deposits in the county. Additional data for the McLean County well database were obtained from the Illinois State Water Survey (ISWS). Engineering boring data have also been obtained from engineering firms in the region.

Data Entry of Well Information, Junkins, Denhart, hourly assistants In connection with GIS Screening for County Solid Waste Siting, temporary data entry staff were hired from UI-UC Temporary Services to assist in the entry of well data. Data include water well driller descriptions for Adams, Carroll, De Kalb, Grundy, Kane, Kankakee, Kendall, La Salle, Macon, and McLean counties, as well as parts of Cook, De Witt, Du Page, Piatt, Ford, Iroquois, and Lake Counties. To date, the project team has entered 206,663 descriptions of geographic units encountered in 37,511 wells. The data will

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(A) Philip C. Reed, hydrogeologist, measures outflow from a saltwater spring along the Saline River. (B) B. Brandon Curry, geologist, looks at the exposure of an ancient lake deposit in a sand and gravel pit in Kane County. (C) Sam V. Panno, geochemist, measures water level in a fen-wetland complex near Crystal Lake, Illinois. (D) Chemists Richard A. Cahill and Gary B. Dreher review a database on radon in Illinois homes.

be valuable for assessing groundwater resources and evaluating land capacity for landfill siting. Also completed was the uploading of a file on noncoal mine data, including 1,890 locations for mines, pits, and other mineral operations.

Hazardous Wastes

Underground Injection Control Class I Service Program *E. Smith, Xu* The ISGS continues to provide technical expertise and advice to the Illinois Environmental Protection Agency and the U.S. Environmental Protection Agency, Region V, in the Class I Underground Injection Control Program. Activities include review of permit applications, permit modifications, monthly operating reports, and other related technical documents pertaining to the hazardous waste injection wells. Also included are reviews of the local, regional, and provincial geologic and hydrogeologic factors that may influence conditions at these sites. The information submitted by injection well operators in the monthly operating reports is continually updated a computerized database. The results of three mechanical integrity tests were reviewed in the past year. Comments for two permit renewal applications were also submitted. These wells have subsequently been reclassified as nonhazardous Class II wells. Changes in federal and state monitoring report requirements required modification of the computer database to include additional information submitted in the monthly operating reports.

Low Level Radioactive Wastes

Geology of the Martinsville Alternative Site for Low Level Radioactive Waste Disposal, *Curry, Berg* The findings of the ISGS, working with contractors for Battelle Memorial Institute, on the glacial drift at the proposed site for disposal of low level radioactive wastes in Martinsville, Clark County, are contained in a report now in review. A complex but predictable sequence of Illinoian glaciogenic diamicton (till), sand and gravel (outwash, preglacial alluvium), and lacustrine silts overlie the site.

Low Level Radioactive Wastes: Bedrock Stratigraphy of the Geff Alternative Site, *Weibel, Berg* A report on the near-surface bedrock stratigraphy of the proposed Geff site for disposal of low level, radioactive wastes was completed and submitted to Battelle Memorial Institute, the main contractor on this project. The report describes the rocks and correlates selected lithologic beds within the succession. The report was published in the ISGS Open File Series. A review of the procedures for characterization of bedrock stratigraphy at the Geff site was also published in the journal, *Environmental Geology and Water Resources*. The paper suggested modifications for future studies to characterize sites for the disposal of low level nuclear waste.

Technical Assistance to the Illinois Department of Nuclear Safety for Martinsville Site Development, *Berg, K. Cartwright* The ISGS began a technical assistance program for IDNS regarding development of the

Martinsville site for low level radioactive waste disposal. The initial task is to cooperate with the site developer, Chem-Nuclear Systems, to review the site development modeling plan and implementation.

In September and October 1991, ISGS scientists provided about 30 hours of expert testimony to the Siting Commission for Disposal of Low Level Radioactive Wastes in Illinois. Several days were also spent preparing for the hearings and attending other testimonies. The ISGS testified that the Martinsville site was adequately characterized. Many questions were answered concerning the work of consultants.

Coal Wastes

Use of Wastes from Fluidized-Bed Combustion in the Reclamation of Coal Slurry Solids, *Dreher, Roy, Steele* The Illinois Clean Coal Institute (ICCI, formerly CRSC) continued funding of a research project to study the ability of waste from the fluidized-bed combustion (FBC) of coal to neutralize pyrite-bearing, coal slurry solids at coal preparation plants. The overall objective of this research is to develop a method for the disposal of FBC wastes, while simultaneously treating coal slurry solids so that any acid produced by the oxidation of pyrite in the coal waste is neutralized by the alkaline components of the FBC waste. If this research is successful, it could alleviate the need for thick soil covers on reclaimed coal slurry ponds.

Samples of FBC waste were collected from five operators; coal slurry solids were collected from ponds at two coal preparation plants; and agricultural limestone was collected at one quarry. All locations were in central Illinois.

Starting samples were characterized chemically and mineralogically. Particle-size distributions were determined by sieve analysis. Mixtures of FBC waste and coal slurry solids were prepared for laboratory leaching and outdoor weathering experiments. Beginning in February 1992, leachates were collected and analyzed for 30 elements, four anions, alkalinity, Eh, and pH.

EARTH HAZARDS AND GEOTECHNICAL INVESTIGATIONS

Natural and manmade conditions can pose risks to humans and their activities, and cause damage to structures throughout the state. Investigating, understanding, and disseminating the findings to the public can lead to plans to cope with the problems. Landslides and coal mine subsidence impact small areas, whereas earthquakes, radon, and soil properties can cause problems throughout the state. All studies gather valuable information on material properties to aid in the understanding of the mechanisms that cause the problems.

The results of research contribute to a database that is used to respond to inquiries concerning residential and industrial structures and public construction projects. When the highly publicized Chicago "flood" occurred, a consulting firm and a federal agency approached the ISGS for geologic data, technical expertise, and geotechnical interpretations.

Mine Subsidence

Illinois Mine Subsidence Research Program, Bauer, Van Roosendaal, B. Mehnert, Trent, DeMaris, Kelleher The Illinois Mine Subsidence Research Program (IMSRP) continues to coordinate the investigations of program participants: U.S. Bureau of Mines, University of Illinois (UI-UC) Department of Agronomy, SIU-C Department of Mining Engineering, Illinois Department of Mines and Minerals, and Northern Illinois University (NIU) Department of Geology. Research funding for 1992-1993 is partly provided by the Illinois Coal Development Board and the U.S. Bureau of Mines (USBM). The Memorandum of Agreement between the USBM and ISGS was extended until June 30, 1996, to support the cooperative investigation of mine subsidence in Illinois.

The Office of Surface Mining (OSM) awarded a contract to NIU and a subcontract to ISGS for monitoring and drilling to support further study of the effects of longwall mine subsidence on aquifers in Illinois. OSM has selected the NIU/ISGS project as one of two in the nation with critical relevance to this area of research: results may be used to set national regulations concerning water replacement for land affected by longwall coal mining.

Results of ISGS research to monitor the effects of subsidence on surface response, overburden deformation, and groundwater level changes over previously mined longwall panels at the Saline County site showed three-dimensional displacements and strains over an area about the size of a house foundation. Final position of many surface points showed that locations may change permanently by as much as 1.5 feet in the direction of the longwall mining operation, and that surface cracks may develop to a depth of 38 feet. At a second longwall operation in Franklin County, IMSRP and USBM researchers placed a time-domain reflectometry (TDR) cable in a drill hole to monitor subsidence movements. Core is being tested in the ISGS Rock Mechanics Laboratory.

A UI-UC study showed that areas needing mitigation over longwall panels are only 1 to 2 acres per panel. Soybean yields were as high in mitigated areas as in areas unaffected by subsidence. Corn yields reacted more to weather conditions; overall, corn yields were reduced by 19% in the mitigated areas.

Time Domain Reflectometry, Bauer, Dowding (Northwestern University) The final contract report on the application of time domain reflectometry to subsidence monitoring was submitted to the Office of Surface Mining. Investigators developed a simple way to monitor the type of subsidence movements in bedrock. The study showed that it is possible to differentiate tensile and shear movements in the rock mass through monitoring of coaxial cables grouted into boreholes. This technique can be used for monitoring rock mass movements due to manmade and natural causes.

Earthquakes

Paleoliquefaction Features in Illinois, Su Recently discovered "paleoliquefaction" features indicate that it

is possible that a large earthquake or a series of earthquakes occurred in the Wabash Valley seismic zone (as defined by Nuttli) sometime between 2,250 and 7,500 years ago. Additional field and laboratory studies are being performed to ascertain the nature of these features. A proposal to study paleoliquefaction features in Illinois is being prepared to submit to the USGS National Earthquake Hazards Reduction Program for funding. The project will include a field search for more liquefaction features and a detailed geologic and geomorphologic study at Wayne City and Newton, sites of historic earthquakes. The project is designed to determine the regional distribution, possible mechanisms, and ages for the features.

Field Review of Paleoliquefaction Features, Follmer, Su, DuMontelle, Heigold In November 1991, the Indiana Geological Survey and members of the USGS conducted two field reviews to examine paleoliquefaction features (clastic dikes) in the Wabash Valley. Investigating the causes of these clastic dikes was the main objective of the trip. Other organizations were represented by Steve Obermeier (USGS), Eugene Schweig (USGS/Memphis State University), Patrick Munson and Cheryl Munson (Indiana University), Norman Hester and Gordon Fraser (Indiana Geological Survey), John Kiefer (Kentucky Geological Survey), Alberto Nieto (University of Illinois), Steve Wesnousky (Center for Earthquake Studies, Nevada), David Amick and Robert Gelinas (Ebasco Corporation), Terry West (Purdue University). A statement was drafted by the Illinois and Indiana Surveys agreeing that the logical explanation for the dike features is that they were seismic-induced by paleo-earthquake(s). The age of the earthquakes is still under investigation.

Earthquake Risk Map of Southern Illinois, Stiff, McKay, Bauer A preliminary earthquake risk map was prepared for use in a joint FEMA-IESDA earthquake exercise. The small-scale map shows regions of southern Illinois that may be susceptible to landslides, liquefaction, or enhanced ground shaking. The geology of the region is based on the ISGS surficial geology map (1:500,000 scale). Base map information shows major highways, railroads, pipelines, and electrical transmission lines. Large-scale geologic maps would be more useful for local preparedness planning.

Geophysical Investigations of Possible, Recent Ground Deformation and Neotectonism in White County, Illinois, Heigold, Orozco Geophysical investigations are planned for two sites in White County, Illinois, in the Lower Wabash River Valley. The first site is the location of a reported ground deformation that occurred at the same time as the earthquake in the New Madrid Seismic Zone on December 16, 1811. The second site is the location of a geomorphic feature in Holocene sediments; it is closely aligned to the Herald-Phillipstown Fault in the Wabash Valley Fault System, possible evidence of neotectonism in this region. Both of these investigations are consistent with elements of the research priorities of the National Earthquake

Hazard Reduction Program. The former addresses predicting the effects of earthquakes, whereas the latter addresses evaluating earthquake potential.

Enhancement of Body-Wave Amplitudes by Loose, Surficial Deposits, Heigold Evaluation of seismic risk should include analyses of the contribution of poorly consolidated, surficial deposits to anomalously high, seismic intensities. Zoeppritz equations can be used to demonstrate that amplitudes of body waves emerging from competent bedrock can be enhanced as they are transmitted through overlying layers of poorly consolidated (uncemented, nonlithified, nonrigid), surficial deposits.

A study to analyze soil parameters in relation to seismic risk is underway. If the elastic parameters of surficial deposits and subjacent bedrock can be measured throughout a region, then subregions can be defined during large scale, geologic mapping. Areas where enhancement of body-wave amplitudes by surficial deposits is relatively large can then be identified.

Landslides

Landslides in the New Madrid Seismic Zone, Su, Stohr The report, *Landslides in the New Madrid Seismic Zone: Inventory and Risk Assessment along the Ohio and the Mississippi Rivers from Olmsted to Chester, Illinois*, was submitted in March 1992 to the USGS as part of its National Earthquake Hazards Reduction Program (NEHRP). A total of 221 landslides was recognized and classified into three major categories: rock/debris falls (11%), block slides (25%), and rotational/translational slides (64%). Stability analyses of three representative landslides indicate that they would not have occurred under aseismic conditions, but they could have been initiated by earthquake loadings similar to those generated by the 1811-1812 New Madrid earthquakes.

Su and Follmer received an award to continue last year's project with the USGS. The extended project, which began in April 1992, will cover the area from Chester to East St. Louis, Illinois.

Slope Stability Analysis, Killey, Su The slope stability of Quaternary materials in the Middle Fork River County Forest Preserve of northeastern Champaign County was examined in June 1992. The assessment was made at the request of Jack Paxton, plant pathologist at the University of Illinois. A letter reporting on the stability of the slope near the property line in relation to nearby sand and gravel mining operations was sent to John Oldenberg of Champaign.

Automation of the Landslide Inventory Map of Illinois, Pool, Masters, Killey, McKay The Landslide Inventory Map compiled by Killey, DuMontelle, and Brabb (USGS MAP MF-1691, 1984) was digitized at its original scale of 1:500,000 and added to the database of the Illinois Geographic Information System.

Radon

Radon/Natural Radioactivity, Cahill Human exposure to terrestrial radiation arises from radionuclides

distributed in the geologic materials and transferred from the earth to the atmosphere or hydrosphere. The ISGS responded to frequent inquiries from the press, public, consultants, and government agencies on the occurrence of radon in Illinois.

The ISGS indoor radon database of 16,000 measurements and information on location of the test, vendor, and zip code was updated. An updated database (4,100 measurements) on indoor radon was obtained from the Illinois Department of Nuclear Safety (IDNS), and another database (1,800 measurements) was obtained from the U.S. Environmental Protection Agency (USEPA). The mean indoor level of radon in Illinois is near the USEPA guideline level of 4 pCi/L; however, less than 1% of the measurements exceed 20 pCi/L.

The following documents were reviewed: "The USGS/EPA Radon Potential Booklets: An Introduction" (Linda Gunderson and Randall Schumann of USGS and Sharon Wirth of USEPA); "The Radon Potential of Illinois" (Randall Schumann); and "Methodology for the Development of EPA's Draft Map of Radon Zones" (Sharon Wirth). The formal response for the State of Illinois to USEPA Region 5 was coordinated with and submitted by IDNS.

Rock Mechanics and Geotechnical Support

Engineering Geology Database and Geographical Information System, Su The database is currently being used to develop a prototype SQL TABLE of geologic and engineering data presented in the final ISGS contract report, *Geotechnical Site Investigation, 7-GeV Advanced Photon Source, Argonne National Laboratory* (Killey and Trask 1989).

The Engineering Geology Database uses the same Oracle database structure as existing ISGS well data tables. The same primary keys can thus be used to retrieve both engineering geology records and all basic geologic information. AutoCAD and GEO/SQL are used for the GIS application. Information can be viewed on the monitor or printed out, as requested by users. The system contains custom pop-up menus that will assist users to construct SQL commands for retrieving or updating database information. This project is supported in part by the University Grant Program from Generation 5 Technology (Denver, Colorado) and Autodesk (Sausalito, California).

Technology Transfer and Information Services
Mine Subsidence Information Dissemination, Trent, Bauer, Van Roosendaal, B. Mehnert, Kelleher Sixteen papers were released in the IMSRP reprint series during July. During the year, requests for IMSRP publications were received from New Mexico, Kentucky, Ohio, England, and Australia. Search requests on the IMSRP bibliographic database were completed for consultants and engineers in Illinois, Wisconsin, Michigan, and Kentucky.

The IMSRP exhibit was displayed at the joint meeting of the International Society for Mine Surveying and National Mining Symposium in Kentucky (September 1991), at the Illinois Mining Institute in Illinois (September 1991), and at the University of

Illinois Agriculture Open House (February 1992). The IMSRP exhibit was also displayed at the Third Workshop on Surface Subsidence due to Underground Mining, which was held in West Virginia in June 1992.

IMSRP staff took two South African visitors on field trips to research sites during June 1992. J. Nielsen van der Merwe, a group strata control engineer, and Ampie Potgieter, who is responsible for relations with landowners, are both employed by SASOL Coal in Johannesburg. They were in the United States to gather information about the experience of Illinois coal companies with planned subsidence and mitigation. IMSRP staff members set up meetings and accompanied the visitors to the Illinois Coal Association and several coal company offices where they met with industry subsidence mitigation experts. Potgieter and van der Merwe were given tours of IMSRP research sites in Jefferson and Saline Counties.

Also in June 1992, IMSRP staff led a tour of two research sites in Jefferson County for approximately 15 participants in an Office of Surface Mining course, "Underground Mining Technology and Effects."

Computer-Assisted Directory of Mine Subsidence Insurance Claims, Coats, Jaruseski, Bauer Subsidence and nonsubsidence data collected via the Illinois Mine Subsidence Insurance Fund are stored in a PC-INFO database. Information covers structure and foundation type, underground mines, and soils. The database contains 5,230 records and grows by an average of 400 claims each year. Data continue to be collected for a study of structural damage and related soil properties.

Chicago "Flood," DuMontelle, Bauer, Chrzaszowski, Van Roosendaal, B. Mehnert, Kelleher Harza Engineering and the U.S Army Corp of Engineers contacted the ISGS about the process and rate of dewatering. Maps and cross sections of the glacial deposits underlying Chicago were supplied along with a printout of the fill and sand thicknesses, as recorded in borehole logs at the ISGS. This geologic information assured engineers that conditions in the vicinity of the tunnels would likely support a rapid dewatering of the freight tunnel system. ISGS representatives also participated in a meeting with agencies responding to the emergency.



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(A) Geologists Anne L. Erdmann, Brenda B. Mehnert, Myrna M. Killey, and John P. Kempton check a map of a drill site area near Foosland in Champaign County. The area is a demonstration site for new ways of mapping Quaternary sediments. (B) Keith C. Hackley, geochemist, examines coal pellets after combustion for a coal desulfurization project. (C) Geologists Zakaria Lasemi and Michael L. Sargent study the stratigraphy of drill cores from northern Illinois. (D) W. John Nelson, geologist, maps bedrock in Alexander County as part of the COGEOMAP project.



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GENERAL AND BASIC RESEARCH

GEOLOGIC AND TOPOGRAPHIC MAPPING AND REMOTE SENSING

Geologic maps, cross sections, and three-dimensional models show the distribution of geologic materials on and beneath the land surface. Geologic mapping at appropriately large scales is required for resource evaluation, land use planning, environmental protection, and earth hazard identification. Only about 3% of the state has been mapped at a scale of 1:24,000 (1 inch on the map represents 2,000 feet on the ground), the scale considered suitable for most uses. Recently, federal legislation brought the prospect of a statewide program of large scale, geologic mapping closer to realization. On May 18, President Bush signed the National Geologic Mapping Act of 1992—an act that authorizes Congress to provide the funding and directs the USGS to develop a plan for implementing the program. The act requires the states to share the costs equally with the federal government; it also specifies active roles for state geological surveys.

A cooperative program to produce topographic and planimetric maps at different scales is also underway. Compilation of digital cartographic data for integration with geologic and other thematic data through the ISGS Geographic Information System (GIS) is another part of the program. The goal of cooperative mapping with the USGS is to complete the 1:100,000-scale, county topographic map series. The ISGS is also participating in an in-kind cooperative program to complete 1:24,000-scale, digital map products.

In the remote sensing program, aerial photography and remote-sensing imagery are used to collect and analyze data for geologic, hydrologic, and mineral resource mapping.

Basic Geologic Mapping

Illinois Geologic Mapping Advisory Committee, Leighton, Damberger, McKay IGMAC was organized in 1988 to support a major program of geologic mapping in Illinois. Serving on the committee are representatives of industry, academia, and all levels of government. The ISGS Chief is permanent secretary of IGMAC.

Semiannual meetings provide a forum for exchange of perspectives on the need for and potential direction of a state mapping program. The November 1991 meeting at Southern Illinois University at Carbondale (SIU-C) featured the results of geologic mapping in recent years along the southern closure of the Illinois Basin. This mapping is part of COGEOMAP, a joint endeavor of the USGS and ISGS. The May 1992 meeting was held in the offices of the Illinois Department of Transportation (IDOT) in Springfield. Dr. Morris W. Leighton, secretary, reported on the development of a State and Federal Cooperative Geologic Mapping Program in Illinois. Dr. E. Donald McKay discussed means to identify needs and set priorities for mapping. J. James Eidel, Robert Pool, and Colin G. Treworgy of the ISGS spoke on aspects of geologic mapping, computer modeling, and coal resource assessment for the Conterminous U.S. Mineral Assessment Program (CUSMAP).

Geologic Mapping for the Future of Illinois, Leighton, Damberger, McKay, Bhagwat, ISGS Mapping Committee

The report, prepared in cooperation with the Senate Working Committee on Geologic Mapping and assisted by the Senate Geologic Map Task Force, was published early in the report period in a new ISGS series, as Special Report 1. The report had been previously submitted in response to Senate Resolutions 881 (June 1990) and 98 (March 1991) that requested a report summarizing the status of geologic mapping in Illinois, analyzing the benefits versus the costs of geologic mapping, and proposing a plan to geologically map Illinois. The contents of the report were summarized in last year's annual report. A separate report on the benefits and costs of geologic mapping was also published as ISGS Circular 549.

Cooperative Geologic Mapping Program

COGEOMAP, a cooperative ISGS and USGS, program has two major components: mapping 7.5-minute quadrangles in southern and southwestern Illinois, and developing and demonstrating methodology for three-dimensional mapping of glacial deposits on the Champaign 30×60-minute quadrangle in central Illinois.

COGEOMAP Project 1: Geologic Quadrangle Mapping of the Southern Closure of the Illinois Basin, Damberger, Nelson, Devera, Weibel, Jacobson Geologic field mapping under the first project of COGEOMAP was partly supported by the USGS. Work was completed on the bedrock geology of fifteen 7.5-minute quadrangles and is progressing on maps and reports for six of the quads. Three quadrangles were published in the ISGS Illinois Geologic Quadrangle series early in 1992, so the total is now nine. Also, the geologic maps of the Quaternary materials of three quadrangles, completed by students of SIU-C in cooperation with Quaternary geologists at the ISGS, were made available to the public through the ISGS Open File Series.

One more 7.5-minute, geologic quadrangle map was sent out to a computer graphics firm for digitizing and production of negatives for color printing; the job was nearly completed during the report period. The ISGS will receive both the negatives needed to print the maps and digital files of the geologic quadrangle map.

- **Geologic Map of the Goreville Quadrangle, Jacobson** The map was printed during the previous report period and released early in 1992.
- **Geologic Map of the Waltersburg Quadrangle, Weibel, Nelson, Devera** The map was printed in the previous report period and released early in 1992.
- **Geologic Map of the Glendale Quadrangle, Devera** The map was printed during the previous report period and released early in 1992.
- **Geologic Map of the Bloomfield Quadrangle, Nelson** Compilation of the bedrock geology on a greenline base map was completed; also prepared were two cross sections, a stratigraphic column, a brief text describing the geology, and an explanation. Technical,

administrative, and editorial reviews were completed; bids to digitally prepare negatives for printing were received; work on the digital camera-ready map was well advanced at the end of the report period.

• **Geologic Map of the Makanda Quadrangle, Weibel, Jacobson** Compilation on the greenline base and production of the cross section, stratigraphic column, and brief text describing the geology of the quadrangle were completed; the map was sent through technical and administrative review. Comments were incorporated and a final draft prepared for production of camera-ready copy and negatives for color printing.

• **Geologic Map of the Cobden Quadrangle, Nelson, Devera** After compilation of a draft geologic map in the last report period, completion of this quadrangle was put on hold until mapping of adjacent quadrangles was completed and match-up problems with faults and contacts of formations between the quadrangles could be avoided.

Of particular concern were the revised subdivision of the Devonian System into mapping units (formations) and the placement of faults in the Ste. Genevieve Fault Zone that crosses the quadrangle and extends into adjacent quadrangles. Several changes were needed as a result of mapping adjacent quadrangles. Colored blueprints were prepared for review early in the next report period.

• **Geologic Map of the Wolf Lake Quadrangle, Devera** A final draft of the bedrock geology of this quadrangle and the adjacent Gorham Quadrangle to the east, has been compiled on a greenline base map. Review of the two quadrangles will be carried out together early in the next report period.

• **Geologic Map of the Gorham Quadrangle, Devera, Weibel** A draft geologic map was compiled on a greenline base early in the report period, but completion of a final draft was deferred until field mapping of adjacent quadrangles was completed to ensure continuity of mapped geologic units and faults between the quadrangles. A final draft of the quadrangle has been completed and hand-colored blueprints will be submitted for review early in the next report period.

• **Geologic Map of the Altenburg Quadrangle, Devera** Field work to geologically map the quadrangle was completed and a draft geologic map compiled on a greenline base map. Only about one-quarter of this quadrangle lies within Illinois, so it will be published together with the Gorham Quadrangle (to the immediate east) to save printing costs. The map will be reviewed together with the Gorham and Wolf Lake Quadrangles early in the next report period.

• **Geologic Report on the Goreville Quadrangle, Jacobson** This report was produced by the ISGS Publications Unit and published as ISGS Bulletin 97.

• **Geologic Report on the Bloomfield Quadrangle, Nelson** A first draft of this report had been completed some time ago. The report was finalized and technical, administrative, and editorial reviews were completed. Production of camera-ready illustrations is underway.

• **Geologic Report on the Waltersburg Quadrangle, Weibel, Nelson** Technical and administrative reviews were completed; production of camera-ready

copy is well underway in the Publications Unit. The report will appear in the ISGS Bulletin series.

• **Geologic Report on the Makanda Quadrangle, Weibel, Jacobson** A final draft of the report was completed and sent through peer review, which was nearly complete at the end of the report period.

• **Geologic Report on the Lick Creek Quadrangle, Nelson, Weibel** A draft of this report was completed; final touches by the authors are needed before it is submitted for review early in the next report period.

• **Geologic Report on the Glendale Quadrangle, Devera, with contributions by Norby** This report is being revised by the author, taking extensive comments by peer reviewers into consideration. Work on the project was suspended during the field season.

• **Geologic Report on the Cobden Quadrangle, Nelson, Devera** Work on this partially completed report was temporarily suspended, awaiting results of field mapping on adjacent quadrangles.

• **Geologic Report on the Gorham, Wolf Lake, and Altenburg Quadrangles, Devera, Weibel, Nelson** This report is partly complete, but work on it was temporarily suspended to permit consideration of findings on adjacent quadrangles, especially on a revised classification of the Devonian System.

COGEOMAP Project 2: Geologic Quadrangle Mapping in Southwestern Illinois, Nelson, Devera, Masters The USGS and ISGS program of cooperative geologic mapping continues in extreme southern Illinois. The Jonesboro, Mill Creek, and the Illinois portions of the Ware and McClure 7.5-Minute Quadrangles were mapped during the 1991-1992 field season. Drafts of the geologic maps and a report on the geology of the area are undergoing review.

Significant findings of the mapping include the first documentation of post-Cretaceous tectonic faulting in southern Illinois. The area was found to be riddled with small faults, most of which were unrecognized during previous reconnaissance studies. The principal fault trends are north-south, northeast, and northwest. Many of the faults appear to contain significant components of strike-slip displacement. Unlithified sand, gravel, and clay deposits of the Upper Cretaceous McNairy Formation and possibly the Eocene Wilcox Formation are displaced by some of the faults. Moreover, anomalous drainage patterns in the study area raise the possibility that tectonic deformation continued into the Quaternary Period. This activity is presumed to be related, at least in part, to the New Madrid Seismic Zone immediately south of the mapping area.

Plans for the 1992-1993 field season call for mapping the Tamms and Dongola 7.5-Minute Quadrangles. Follow-up studies in the quadrangles mapped last year will assess further the extent and nature of any faulting that may have occurred during the Quaternary. Richard Harrison of the USGS is currently mapping the adjacent Thebes Quadrangle. He reports that the Pliocene to early Pleistocene Mounds Gravel is tectonically deformed in the Missouri part of the Thebes Quadrangle. The studies cited aim to more accurately assess the risk of earthquakes in southernmost Illinois.

Another outcome of the 1991-1992 mapping concerns the origin of the commercial microcrystalline silica (tripoli) deposits of extreme southern Illinois. The study finds that silica deposits are confined to areas of intensely fractured bedrock. As previously proposed by John M. Masters and Richard B. Berg (ISGS Illinois Minerals series, in preparation), low temperature hydrothermal fluids evidently leached and silicified the fractured rocks. The hypothesis of hydrothermal fracturing contrasts with earlier theories that attributed the origin of silica to intense surficial weathering.

COGEOMAP Project 3: Three-Dimensional Geologic Mapping of Quaternary Deposits in the Champaign Quadrangle, Illinois, Kempton, Berg (ISGS); Soller (USGS) Goals for the current project year include developing the basic mapping methods and data compilation procedures, building a database, identifying the key stratigraphic controls, and drafting a preliminary geologic province map. Several thousand items of information (key stratigraphic sections and borings, and water well sample sets) have been inventoried and evaluated; their locations have been checked and plotted on 1:24,000-scale topographic maps. Water well sample sets and key stratigraphic control boring samples were studied, and work on a geologic province map started. Bids to drill two exploration holes were received and a drilling contractor selected in late June. The results will provide additional key stratigraphic control. As part of their contribution to COGEOMAP, the USGS scheduled their drilling rig for sampling two or three sites in late August 1992.

A Methodology for Displaying Three-Dimensional Lithostratigraphic Relationships in Color, Berg, Greenpool Color shading and line and dot patterns were used to develop a methodology to help visualize complex three-dimensional geology. The system to depict the upper rock was tested on the stack-unit map to a depth of 50 feet for the Paducah $1^{\circ} \times 2^{\circ}$ Quadrangle. Conditions of stack-unit sequences were sorted according to material type as well as generic-like sequences, then colors and patterns were assigned. This research will be reported in an ISGS Circular, which is currently in editorial review.

Derivative and Topical Mapping

Computer-Assisted Methods of Mapping Subsurface Quaternary Geology, Smith, Stiff, McKay Computer-assisted methods to map subsurface geology are being developed, analyzed, and refined to aid in geologic mapping. The emphasis of this research is to produce and analyze new data-handling techniques, along with new types of maps and visualizations, to (1) portray spatial variation of the lithology of near-surface (less than approximately 500 feet) glacial deposits; and (2) develop computer models, both two and three dimensional, of the glacial succession. Glacial and associated fluvial and lacustrine deposits have been emphasized because they are complex and ubiquitous in Illinois.

An additional objective is to develop methods that make the maximum feasible use of existing borehole

data in the ISGS files. To best utilize these data, the ISGS has developed a computerized database of borehole descriptions. To date, approximately 134,000 wells have automated lithologic descriptions. Computerized methods are needed to expedite the use of this substantial database and make computer analysis of geologic data cost-effective. This research is partly funded by a research grant from the Institute of Environmental Studies, University of Illinois at Urbana-Champaign (UI-UC), and a grant from the Illinois Department of Energy and Natural Resources (ENR).

Test Drilling in Lake County to Evaluate Geologic Map Accuracy, McKay, Stiff, Riggs Three boreholes were drilled in the north-central part of Lake County to test the accuracy of geologic mapping of thick subsurface sand and gravel deposits and to evaluate their stratigraphy and origin. The presence and extent of these deposits were first indicated in computer modeling from water well drillers' descriptions provided to the ISGS. Using more than 8,000 of these records from a 250-square-mile area, ISGS geologists prepared computer models and preliminary maps of the lithology and thickness of glacial deposits.

With the support of an ENR grant, a 5.9-mile-long, east-west, three-hole transect was drilled across a suspected major boundary representing the eastern limit of thick sand and gravel deposits. Results from the continuously sampled holes confirm the mapping. The western and middle holes each encountered sand and gravel deposits more than 100 feet thick at depths greater than 100 feet. The easternmost hole encountered less than 3 feet of sand and gravel in 240 feet of glacial deposits. The total thickness of glacial deposits was predicted with an error of 9 to 20 feet in each of the three borings; measured total thicknesses ranged from 229 to 245 feet.

Topographic Mapping

Cooperative Topographic Mapping, Stohr, Gross, McLean, Abert, Pool, Riggs, Smith, Stiff, Taylor, Witzany, McKay During the past year, revised or updated editions of 115 7.5-minute quadrangle maps of Illinois were published by the USGS alone, or as a part of the Illinois cooperative program. Orthophotographs (with rectified and radial distortion removed) were published for 148 one-quarter quadrangles and thus raised the total mapped area to 42% of the state. Of the 46 maps in the 1:100,000-scale, 30×60-minute series, all but one have been converted to topographic format. The 1:100,000-scale county map series, being completed under a joint funding agreement, now includes 58 maps; five were completed as topographic editions.

Digital elevation data are available for nine quadrangles at the 1:250,000 scale, 22 quadrangles at the 1:100,000 scale, and 211 quadrangles at the 1:24,000 scale (50 others are in progress). As part of the Solid Waste and Environmental Trends contract through ENR, staff completed computer processing of digital elevation data for thirty-three 7.5-minute quadrangles covering McLean County. A preliminary set of data was delivered to the USGS Midcontinent Mapping

Center in Rolla, Missouri, for evaluation and inclusion in the National Digital Cartographic Data Base.

Remote Sensing

A Method for Detecting Problems in Landfill Covers, Stohr Detecting leaky landfill covers was the focus of a proposal accepted in January by the Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas. Field data that included shallow soil borings, soil samples for moisture content, and measurements of methane concentrations were collected. Aerial, thermal, infrared data were also collected with the assistance of the Division of Aeronautics of IDOT.

CRUSTAL STUDIES

Studies of the crustal framework in Illinois provide information about the origin and development of the Illinois Basin and surrounding domes and arches, the controls on distribution of natural resources, and deep crustal structures that influence earthquake activity.

Knowledge of the Midcontinent crustal framework has increased significantly in recent years as a result of regional geophysical studies. Studies included deep, seismic reflection profiling across the Illinois Basin by the oil and gas industry and by the Consortium for Continental Reflection Profiling (COCORP); deep, seismic reflection profiling in the southern Illinois Basin by the USGS; and gravity and magnetic mapping of Illinois through the cooperation of the ISGS and USGS. Analyses of data from these studies are far from complete; in some cases, more data must be acquired.

Industry-sponsored reflection profiling has focused primarily on Phanerozoic rocks that contain mineral resources. The ISGS is making an effort to acquire proprietary, geophysical data to increase its seismic library—a vital database for basin analysis and mineral resource assessment. Focus of research during the report year was on (1) interpretation of proprietary, seismic reflection profiles near Hicks Dome in southern Illinois; (2) interpretation of seismic reflection profiling over King Field in Jefferson County; (3) geophysical investigations of possible ground deformation and neotectonism in White County; (4) magnetic and gravity study of the Paducah Quadrangle (CUSMAP); (5) statewide compilation of aeromagnetic and gravity anomaly maps; and (6) analysis of a Proterozoic crustal boundary in the southern Illinois Basin.

Deep Seismic Data

Interpretation of a Regional Seismic Reflection Line, Southern Illinois Basin, Heigold A high quality, seismic reflection profile across the transition zone between the Reelfoot Rift and the Rough Creek Graben provides subsurface constraints on a tectonically complex area of the southern Illinois Basin. Prominent geologic structures along the profile include the Shawneetown-Rough Creek Fault Zone, Hicks Dome, the Fluorspar Area Faulted Complex, and the Taft and the Pennyville Fault Systems. The data provide new information on the development of the Cambrian Rift

System, the origin of Hicks Dome, and the relationship between faulting and mineralization.

Seismic data show that the Cambrian Rift System along the profile is a half-graben that thickens to the southeast, in contrast to the northward-thickening geometry of the Rough Creek Graben farther to the east. Reflection patterns near Hicks Dome are consistent with the hypothesis that the dome originated from explosive release of mantle-derived gases associated with alkali volcanism.

Correlation of the reflection data with surface mineralization patterns show that, in most cases, mineralized surface faults clearly cut basement or are splays from faults that cut basement.

Potential Field Investigations

Statewide Gravity and Magnetic Maps, Heigold Aeromagnetic maps at scales of 1:1,000,000 and 1:500,000 and gravity maps at scales of 1:500,000 and 1:250,000 for the entire state of Illinois have been compiled through a cooperative effort between the ISGS and USGS. These maps, which will be published in fiscal 1993, provide information about the structure and composition of the earth's crust.

Crustal Synthesis

Proterozoic Crustal Boundary in the Southern Part of the Illinois Basin, Heigold, Kolata Acquired COCORP and proprietary seismic reflection data for the southern part of the Illinois Basin, combined with other geological and geophysical data, indicate a west-northwest-trending Proterozoic crustal boundary lies beneath the 1.48 Ga granite-rhyolite terrain within this area. The boundary lies along the projected trend of the northern margin of the Early Proterozoic Central Plains Orogen. The location of the boundary between the Wabash Valley Seismic Zone and the New Madrid Seismic Zone to the southwest may be a significant factor in the present-day seismicity of these two regions. During the past year, a manuscript was submitted and accepted for publication in the Dutch journal, *Tectonophysics*.

BASIN ANALYSIS

The Illinois Basin covers approximately 60,000 square miles in the southern two-thirds of Illinois and adjacent parts of Indiana and Kentucky. The basin contains about 100,000 cubic miles of sedimentary rocks that yield valuable resources, including industrial minerals and metals, coal, oil and gas. These resources have greatly benefited the economic health of Illinois for many years. Basin analysis, a multidisciplinary method of research, contributes to the discovery and development of mineral resources in Illinois by providing information on the geologic framework of the Illinois Basin, and thus improving predictions of mineral resource occurrences.

The ISGS Basin Analysis Program integrates geological and geophysical data to increase understanding of how the basin formed, filled with sediment, and changed after burial. The primary focus of

research in the last year was on (1) construction of cross sections showing the structural and stratigraphic framework of the basin; (2) quantitative modeling to determine the mechanisms of tectonic subsidence in the Illinois Basin; (3) stratigraphic analyses of selected Cambro-Ordovician rocks to determine facies relationships; (4) construction of cross sections of the Mississippian Pope Group in the southern part of the Illinois Basin; (5) conodont biostratigraphy of selected lower Paleozoic rock units to facilitate rock correlation; and (6) correlation of Ordovician volcanic ash beds. To capitalize on existing facilities and expertise, the ISGS has continued its cooperative research programs with the Indiana and Kentucky Geological Surveys as well as with the U.S. Geological Survey.

Framework Studies

Tectonic Subsidence History of the Illinois Basin, J. Treworgy, Kolata, Sargent To better understand the processes of basin forming and filling, analyses were performed to determine the percentage of basin subsidence due to tectonic subsidence through Paleozoic time. Subsidence was quantitatively modeled for several deep wells in the southern part of the Illinois Basin. Modeling included (1) incrementally decompacting sediment fill through time to restore true sediment thicknesses at given times, and (2) incrementally backstripping stratigraphic units to remove subsidence effects due to sediment loading at given times.

Results indicate that tectonic subsidence was controlled by three mechanisms: rifting, thermal subsidence, and an isostatically uncompensated mass in the lower crust. The same tectonic subsidence pattern was apparent in all the wells, although magnitude decreased toward the north away from the rift.

The results and a discussion of the interplay of tectonic subsidence with eustatic sea-level change and epeirogeny were presented to the Geological Society of America (GSA) North-Central Section in Iowa in April.

Illinois Basin Cross Section Project, J. Treworgy, Whitaker The Illinois Basin Consortium (IBC), consisting of the Illinois, Indiana, and Kentucky Geological Surveys, is preparing 20 regional structural cross sections of the Illinois Basin. The sections are providing valuable information on the structural history and stratigraphic framework of the basin. The sections are fundamentally important in the development of nearly all subsurface research projects in the basin.

The sections are composed from wireline logs of the deepest wells available and portray the entire Phanerozoic section from the top of Precambrian basement (as deep as 24,000 feet in places) up to the surface. During this report period, wireline logs were digitized and "skeleton cross sections" (without geological interpretations) were generated for the remaining 13 cross sections. Most of the work was done by Energy Data Services in Denver with the financial support of the USGS. Project supervision and quality control was provided by the ISGS.

Four cross sections were completed and made available to the public, so the total completed is now

seven. Three of these were also part of the CUSMAP Project. All of the cross sections were presented at the public meeting in St. Louis for the CUSMAP Project, and five were presented at the annual meeting of the North-Central Section of GSA in Iowa in April.

Structural Geology and Tectonic History

Basin and Structural Analysis of Part of the La Salle Anticlinorium, Eastern Illinois, Lumm This study is funded by the USGS Branch of Sedimentary Processes. The major objective is to examine in detail the extent, thickness, and character of individual rock units near the southern terminus of the La Salle Anticlinorium in parts of Crawford, Jasper, Lawrence, and Richland Counties. The south-southeast-trending structure is expressed in the subsurface by deformed strata of Cambrian through Pennsylvanian age composed mostly of sandstone, shale, and limestone. Although the major rock units thin eastward across the structure, there is general agreement that this thinning is the result of movement on the structure during sedimentation; it has not yet been determined lithologically how this thinning takes place.

The data used for this study consist of approximately 400 borehole geophysical logs, 300 well sample cuttings, and 20 partial core samples of Pennsylvanian and Mississippian strata. Preliminary results indicate that the upper Chesterian limestones are abruptly truncated eastward and replaced by sandstone bodies presumed to be of Pennsylvanian age.

Burial and Thermal History Studies

Diagenetic History of the Maquoketa Shale: Mineralogy of the St. Peter Sandstone, Moore, Grathoff, Hughes, Crockett, Glass (ISGS); Shaw (Queens University); Velde (École Normale Supérieure); Pittman (USGS) Development continued on a method to differentiate clays deposited with sediments from clays formed chemically after sediments were deposited. The latter relate to the thermal conditions necessary for the formation, movement, and emplacement of petroleum. The focus of research has been the mineral content of Maquoketa shales and the St. Peter Sandstone. The former may have been petroleum source rocks; the latter is equivalent in age and other characteristics to strata containing natural gas reservoirs in the Michigan Basin.

About 150 more samples of the clay-size fraction of the St. Peter Sandstone have been analyzed; most samples for the St. Peter Sandstone study were completed. Additional samples will be analyzed to refine the basin thermal model derived from the Maquoketa study and to clarify the mineral alteration sequence found in the St. Peter.

Stratigraphy

Tectonomagmatic and Stratigraphic Significance of Ordovician Volcanic Ash Beds in Eastern North America and Northwestern Europe, Kolata (ISGS); Huff (University of Cincinnati); Bergstrom (Ohio State University) The goal of this project is to determine whether Ordovician-age ash beds (450 million years old) in eastern North America, including the Illinois Basin, can

be correlated with the same age ash beds in northwestern Europe. The apparent worldwide distribution of the ash beds has implications in the search for mineral resources. It could provide an accurate reference for timing of geologic events. In addition, the scientific community has shown considerable interest in the effects of these large ash falls on global extinction.

During this report period, the National Science Foundation provided a new grant to continue work on the project through 1994. In addition, a manuscript was accepted for publication by the journal, *Geology*.

Silurian Volcanic Ash Beds in the Iapetus Region: A Preliminary Event-Stratigraphic and Tectonomagmatic Assessment, Kolata (ISGS); Huff (University of Cincinnati); Bergstrom (Ohio State University) The goal of this project is to record the occurrence of Silurian volcanic ash beds in eastern North America, including the Illinois Basin, and in northern Europe. A review of the regional biostratigraphic and geographic distribution suggests that single beds or complexes of beds may be potentially useful for intercontinental correlation. They may provide time constraints for geologic processes that involve wide regions of the northern hemisphere. During this report period, a paper was revised and accepted for publication in the Swedish journal, *Geologiska Foreningens i Stockholm Forhandlingar*.

Sample Studies of Deep Wells in the Illinois Basin, Lasemi, Shaw (Queen's College, New York); J. Treworgy, Sargent (ISGS) Samples of drill cuttings of key intervals from deep wells around the Illinois Basin are being studied under binocular scopes to better understand the facies relations and depositional settings of certain intervals. The focus is currently on the lower part of the Ordovician Champlainian Series in which correlative rock or facies changes occur across the basin. Thorough understanding of this interval could lead to identification of paleoaquifers and potential source rocks, migration pathways, and reservoirs for hydrocarbons, as well as a better idea of the depositional and tectonic history of that time.

Geology of Basal Pennsylvanian Rocks in the Illinois Basin: The Tradewater Working Group, Devera, Nelson Geoscientists from several institutions formed a research team to study lower Pennsylvanian rocks in the Illinois Basin. The group has expertise in a wide range of fields including sedimentology and depositional environments, paleontology, coal petrography and palynology, and surface and subsurface stratigraphy. A review of the project was given at the meeting of the Illinois Basin Consortium in New Harmony, Indiana, in May 1992.

Standardization of Illinois Basin Pennsylvanian Formational Nomenclature, Jacobson, Damberger, Nelson, Weibel (ISGS); Williamson, Greb, Williams (Kentucky Geological Survey); W. Hasenmueller, N. Hasenmueller, Eggert, Ault (Indiana Geological Survey); Hopkins, Wilson (Peabody Coal Company); Langenheim (UI-UC) The three state geological surveys active in the Illinois

Basin agreed on standardizing nomenclature for rock formations and groups throughout the Basin. Numerous changes were made in a draft manuscript as a result of discussions and reviews among the authors and other experts on Pennsylvanian stratigraphy. The report, now in peer review, will soon be published cooperatively by the three state surveys in the Illinois Basin Studies series.

Distribution of the Caseyville Formation in the Subsurface of the Illinois Basin Coal Field, Jacobson The oldest formation of coal-containing Pennsylvanian strata deposited on the major pre-Pennsylvanian unconformity will be better understood as a result of this study. The information bears on oil, gas, and coal resources in the basin. Logs for the first of eight planned northwest-southeast cross sections were selected and interpreted, and sample sets of drill cuttings studied. Although a draft of the first section was completed, the project has been postponed because of budget constraints.

Sequence Stratigraphy in Mixed Clastic-Carbonate Strata, Upper Pennsylvanian, East-Central Illinois, Weibel The ISGS hosted the 21st Annual Field Conference of the Great Lakes Section of the Society of Economic Paleontologists and Mineralogists (SEPM) in Effingham in October 1991. The conference was well attended by geologists from universities and state surveys of most midwestern states and Kansas, Georgia, Pennsylvania, and New Jersey. Dr. Weibel organized the conference; the keynote speaker was Lawrence L. Sloss, Professor Emeritus of Northwestern University and former long-time member of the Board of Natural Resources and Conservation. Proceedings of the conference were published by the Great Lakes Section of SEPM.

Field Trip of the 21st Annual Field Conference of the Great Lakes Section of SEPM in Effingham in October 11-12, 1991, Weibel (ISGS); Langenheim (UI-UC); Stratton (Eastern Illinois University) The six field trip stops were described and depicted in a field guide discussing the sequence stratigraphy of the Upper Pennsylvanian strata of east-central Illinois.

Application of Cyclothem-Based Sequence Stratigraphy to Upper Pennsylvanian Strata, East-Central Illinois, Weibel The paper was published as part of the Great Lakes Section of the SEPM 21st Annual Field Conference. It reviews the rise and decline in usage of the cyclothem of Wanless and Weller (1932) and examines the application of cyclothems to the strata in the area of the field trip. The relationship of cyclothems to the hierarchy of sequence stratigraphy is discussed. An allostratigraphic classification system, based on the cyclothem, is proposed for these strata.

Current Status of Conodont-Based Biostratigraphic Correlation of Upper Pennsylvanian Succession between Illinois and the Midcontinent, Heckel (University of Iowa); Weibel Published in the guidebook for the

field trip organized for the SEPM Great Lakes Section annual meeting, this paper updates and summarizes correlations of Middle and Upper Pennsylvanian marine zones between the Midcontinent (Iowa, Kansas, Missouri) and the Illinois Basin. The correlations are based on detailed, biostratigraphic studies of conodonts extracted from marine limestones and shales. Each widespread marine zone is part of a distinct transgressive-regressive succession. The distinctive aspects of the conodont fauna from each marine unit are used to establish a conodont-based framework of correlation for the cyclic Pennsylvanian strata of the interior of the North American craton.

Sequence Stratigraphy Applications to Pennsylvanian Strata in Illinois, Weibel This paper was presented at the symposium, "Paleozoic Sequence Stratigraphy," sponsored by the Great Lakes Section of the Society for Sedimentary Geology. The event was the Annual Meeting of the North-Central Section of GSA held in Iowa City in April 1992. Application of sequence stratigraphic concepts to Upper Pennsylvanian cyclic strata in Illinois results in a modification of the Wanless and Weller cyclothem. This modified cyclothem is a superior stratigraphic unit because it is practical for stratigraphic control, structural control, differentiation of sedimentological packages, and hydrostratigraphic applications.

Paleoenvironmental Studies

Oakland Concretions from the Energy Shale, DeMaris, Moore An evaluation of the concretion flora will be combined with geochemical and mineralogic examination of the concretions and the enclosing shale. Initial geochemical data have been collected and plans made to examine selected concretions. Processing of concretions for fossils recovered only plant fossils and driftwood. This project has been postponed because of budget constraints.

Fusain Lenses in the Herrin Coal, DeMaris Large, relatively pure fusain lenses have been seen in four mines around the Illinois Basin. These observations suggest that they are widespread, rather than local features of the Herrin Coal. Fusain lenses result from forest fires either at the site of their occurrence or in their vicinity, and thus they lead to important insights into the paleoecology of peat swamps from which coals formed. Commonly, cell structure is well preserved and permits recognition of plants that were subject to combustion. Research is underway on the nature and in-seam stratigraphy of these lenses and what they may reveal about depositional environments of coal swamps. More than 12 new, full seam descriptions have been completed, and many samples of fusain were collected for petrographic analysis. This project has been postponed because of budget constraints.

Synthesis

Illinois Basin Consortium, Staff of the Illinois, Indiana, and Kentucky Geological Surveys The Illinois Basin Consortium (IBC) was organized in 1989 to develop a

better understanding of the Illinois Basin through exchanges of information and cooperative basinwide studies. The consortium is coordinating efforts to avoid duplication of work and take advantage of facilities and expertise at the three state surveys. During this report period, a program plan was published by the ISGS. It is anticipated that the plan will facilitate the integration and coordination of research activities.

The IBC also progressed substantially in its cooperative research with the USGS on the program, Evolution of Sedimentary Basins. The USGS began several projects that will focus on the gas/fluid/rock interactions that have modified the basin through time.

Evolution of Sedimentary Basins, a Cooperative Study Between the Illinois Basin Consortium and the U.S. Geological Survey, Kolata and staff The Illinois Basin is one of six sedimentary basins that is the focus of the cooperative IBC and USGS program, Evolution of Sedimentary Basins. During this report period, 12 projects related to fluid/rock interactions in the Illinois Basin were being conducted by the USGS and IBC. It is anticipated the research will lead to a better understanding of the nature and timing of fluid movement that resulted in migration of hydrocarbons, formation of ore deposits, and basinwide alteration of the sedimentary succession.

Jennie Ridgley reported at the IBC meeting in May 1992 that the USGS was purchasing several regional, high resolution, seismic reflection lines for use by the IBC, and that a digital base map of the Illinois Basin was expected to be completed by the fall of 1992.

Development of a Database of Digitized Wireline Logs, J. Treworgy Wireline logs for about 225 drill holes in the Illinois Basin were digitized during the course of a major cross section project. In this report period, a database of these digitized logs was set up on the VAX computer. A list made of the drill holes includes basic well header information, log types, and depths digitized. Explanations of the data formats, as well as several programs that convert the data to different formats, are included in the database. The database is available to ISGS staff and will eventually be available to the public.

Conodont Biostratigraphy of the New Albany Shale in the Southeastern Portion of the Illinois Basin, Norby (ISGS); Ettenson (University of Kentucky) An updated time framework based on conodonts (a microfossil) has been formulated for Upper Devonian/Lower Mississippian rocks of Indiana and Kentucky. The revised framework will be more accurate for determining ages of various Upper Devonian rock units throughout the Illinois Basin. Knowing the age of these rock units may make it possible to identify geologic structures or stratigraphic traps that may contain oil or gas.

Last year, a summary paper was published. Also, additional samples were processed from old sections. The new information will be presented at the Eastern Section meeting of the AAPG in September 1992.

Structural Geology and Tectonics of the Rough Creek Graben, Western Kentucky and Southeastern Illinois, Lumm, Nelson This field trip and ISGS guidebook (in press, May 1992) are for the GSA Annual Meeting convening in Ohio in October 1992. Several highway and railroad cuts that will be examined expose structural features of the Rough Creek Fault Zone, the Lusk Creek Fault Zone, and the Pennyrite Fault System. All bound the Rough Creek Graben, a buried rift that evolved in Late Precambrian or Early Cambrian time.

QUATERNARY INVESTIGATIONS

Most ISGS sections and many projects deal with Quaternary deposits, surface features, and history. The applied and service sections are also making increasingly significant contributions to various areas of Quaternary knowledge while carrying out sponsored, including mandated, research. The Quaternary Framework Studies Section has provided and/or coordinated many basic studies, including studies of the state's geologic framework, review and updates of stratigraphic classification and nomenclature, and interpretation of geologic processes and environments of deposition. These studies support regional (small scale) and 7.5-minute quadrangle (large scale) mapping and correlation of Quaternary deposits. This mapping is necessary to avoid inconsistencies in stratigraphic classification and nomenclature between map areas. The studies also support the various applications and a growing service load. With the recent signing of the National Geologic Mapping Act by the President, these studies take on additional importance.

Framework Studies

Quaternary Framework of the Lake Michigan Lobe Region, Hansel (ISGS); W. Johnson (UI-UC) Description of glaciogenic sequences, establishment of radiocarbon age control, and correlation of sediments and events in the Lake Michigan Lobe region continues in an attempt to better understand the sediment record and glacial and postglacial history of the lobe. Such understanding is critical in applied studies, because it allows one to predict more accurately what is likely to be encountered in the subsurface in areas where site-specific information is unavailable. Dr. Hansel presented a seminar talk on this topic at the Illinois State Museum Research and Collections Center. A paper relating fluctuations of the lobe with sediments, landforms, and events of the last glaciation is in press in a honorarium volume to be published by the Swedish Geological Survey. A guidebook on the sediment record in northeastern Illinois and northwestern Indiana was reprinted in the ISGS Guidebook series.

Review and Revisions of Quaternary Classification and Nomenclature, Quaternary Framework Studies Section Work continues on the Wedron Formation. Staff have also initiated a review of the loess units (Peoria, Richland, and Roxana), the Illinoian and pre-Illinoian deposits, and other lithostratigraphic units.

• Wedron Classification Revision, Hansel (ISGS); W. Johnson (UI-UC) In the 22 years since the original classification of Quaternary deposits in Illinois by Willman and Frye, continuing studies have generated much new information, particularly about the deposits of the last (Wisconsinan) glaciation. The new data call for revisions of the original classification of the Wedron Formation, which contains most of the deposits of the last glaciation. The reclassification consists of changing the rank of some units, revising the boundaries and conceptual definition of some units, abandoning some units, renaming some units so that their names do not contain genetic terms, incorporating some units defined in Wisconsin, and formally recognizing an early-defined unit as a formation in the new system. The reclassification, which is prepared according to the guidelines set forth in the 1983 North American Code of Stratigraphic Nomenclature, is in review for publication in the ISGS bulletin series.

• Review of the Pre-Illinoian, Killey, Kempton Work on the pre-Illinoian deposits of western Illinois began during this report period with a review of published literature, studies of samples from engineering borings, a preliminary field review of described sections, and integration of clay mineral data from earlier investigations in the area. The investigation will characterize pre-Illinoian sediments in western Illinois, map their distribution and occurrence, make necessary revisions to the classification and nomenclature, and apply this knowledge toward characterization of the area for resource information and land use potential. The work will be coordinated with the pre-Illinoian studies that are a part of the ongoing COGEOMAP project in the Champaign Quadrangle.

Quaternary Environments and Processes

Paleohydrology of Illinois, Curry The nature of the last interglacial to glacial transition that occurred from about 120,000 to 60,000 years ago may be understood better following this study of paleolacustrine sediments and fossils in Illinois. Ostracodes and pollen from cores taken from Montgomery and Fayette Counties are being identified and counted; indications are that a relatively dry phase occurred at the onset of the last glaciation. Other sites indicate that the full glacial climate in Illinois (ca. 18,000 radiocarbon years before present) at about 38° north latitude was similar to modern eastern Minnesota.

Loess Studies Along the Wabash River, Follmer Leon R. Follmer and David Grimley, University of Illinois, met with Thomas Lowell and Rose Hayward, University of Cincinnati, in November 1991 to reevaluate field studies in the loess deposits along the Wabash River. Magnetic susceptibility profiles suggest that up to six cycles of stability and depositional activity occurred during the last glacial stage (from 25,000 to 10,000 years before the present). Morphological studies and radiocarbon dating are underway to assess the age and significance of the susceptibility cycles, which can be used to subdivide and correlate beds in the Peoria Loess across the Midwest.

Regional Loess Studies *Follmer, others* As a part of ongoing studies to relate the characteristics of loess deposits with climatic changes, Dr. Follmer organized a working tour with three graduate students (Dave Grimley, Wang Hong, and Troy Cox [UI-UC]) to pursue dissertation research in the Mississippi Valley from Illinois to Louisiana. Exposures were examined and samples collected to study (1) the isotopic composition of soils in relation to the composition of present rainfall, (2) correlation parameters in loess and paleosols, and (3) regional patterns of bioturbation in soils.

Collaboration in field studies was made in Arkansas, Louisiana, and Tennessee with the USGS, the U.S. Department of Agriculture Soil Conservation Service, and local geoscientists on establishing reference sections for comparison of surficial deposits and calibration of climate changes across the Midcontinent.

Glacigenic Lithofacies and Sequence Studies, *Hansel (ISGS); W. Johnson (UI-UC)* Detailed descriptions of the lithofacies exposed at key outcrops makes it possible to identify the major facies associations commonly found in glacigenic sequences of Illinois. Understanding the facies relationships in the glacigenic sequences makes it possible to determine, for example, whether or not a sand and gravel body found in subsurface borings is likely to be connected to adjacent aquifers. The information is useful for management of geological resources and land. A paper on this topic was used in a short course and presented at the 34th Annual Meeting of the Association of Engineering Geologists in Chicago.

Subglacial Till Genesis and Ice Sheet Dynamics, Lake Michigan Lobe Area, *Hansel (ISGS); W. Johnson (UI-UC); Clark (OSU); Alley (PSU)* Work on understanding and modeling the dynamics of the Laurentide Ice Sheet continues for determining to what extent a deforming subglacial bed may have controlled glacier flow, erosion, and sediment transport and deposition in the Lake Michigan Lobe during the last glaciation. The research has important implications for paleoclimatic reconstruction and the mechanisms for ice sheet growth and collapse, as well as for understanding the glacial sediment record of Illinois.

Sediment flux, glacial transport rates, and possible mechanisms for glacier flow in central Illinois during the early part of the last glaciation were discussed in a paper presented at the GSA Annual Meeting. A paper on the characteristics and genesis of two distinct, subglacial till facies within a single glacigenic sequence was presented at the North-Central GSA meeting. A proposal for interpreting and modeling the Laurentide Ice Sheet in Illinois during the last glaciation on the basis of detailed sedimentological study, geotechnical analyses of the yield and residual strength parameters of till, and sediment flux studies was awarded funding for 2 years from the National Science Foundation.

Technology Transfer and Information Services Participation and Invited Contribution to INQUA Congress on Human and Global Changes During the Quaternary, *Follmer* Dr. Follmer was invited to

participate in the 13th INQUA (International Union for Quaternary Research) Congress held in Beijing, China, from August to September 1991. He presented a paper on the formulation of a soil development scale and a plenary report as Secretary of the Paleopedology Commission. The productivity of the Commission was commended by INQUA.

Participants in an official tour of north-central China examined various loess deposits (windblown silt) and soils. Discussions tied stratigraphic studies to the appearance of early man in China about 1 million years ago. At the Loess Research Center in Xian, Dr. Follmer gave a 4-day course on the techniques of the study of paleosols. He also spent 3 days in Hebei Province examining agronomic research on fruit production that appears to be controlled by geologic factors. Both centers wish to expand cooperation with Illinois researchers and to develop exchange programs.

Scientific Exchange with the Geological Survey of Finland, *Hansel, Kempton (ISGS); U. Vaisanen (GSF)* The 6-month exchange between Hansel and Vaisanen in 1990 had several beneficial results. The paper, "Fossil Soil of Karjenkosi and Its Correlatives in Ostrobothnia, Western Finland," coauthored by Hansel, was published by the GSF in 1991. Vaisanen studied the Livingston County area as a part of the pilot study of agrichemicals in rural water wells. Her paper, "As a Scientist in Illinois," was published in the April/May 1991 issue of GEOLOGI (in Finnish, with translation). Vaisanen and Kempton are also completing a study of the Quaternary fill of the middle Illinois segment of the Ancient Mississippi River bedrock valley.

Glacial Geology of the Midwest: Framework and Applications, *Kempton, Follmer, Hansel, Berg (ISGS); Soller (USGS)* A course notebook and lectures were prepared for this event, which was held in conjunction with the 34th Annual Meeting of the Association of Engineering Geologists in Chicago. The course notebook was intended as a preliminary draft of a handbook on procedures and approaches to the study and mapping of Quaternary deposits.

Consultation on the Quaternary Framework of Northeastern Illinois, *Hansel* Consultations were undertaken with (1) ISGS scientists on applied mapping projects in Lake, McHenry, and Will Counties as well as on groundwater and wetland studies in Champaign, Cook, and Du Page Counties; (2) Illinois State Museum scientists on geological mapping in Kankakee State Park and paleoecological reconstruction at Crystal Lake and Wedron; (3) USGS scientists on paleoclimate, lake-level history, and wetlands development in the Chicago area; and (4) Argonne National Laboratory scientists on regional stratigraphy in the Argonne area.

Industry consultants also required Quaternary information for various projects, such as assessment studies for siting (1) a waste-to-energy and cogeneration plant at O'Hare Airport; (2) a proposed, third Chicago airport near Lake Calumet; and (3) a Chemical Waste Management Incinerator at Lake Calumet.

Quaternary information on the Greater Chicago area was provided for an ecological reconstruction study on Somme Woods Prairie Preserve; a "spill" that needed immediate attention in the Englewood area; and the closing of a gas storage facility in the Kankakee area.

Assistance to Fermi National Accelerator Laboratory, Kempton, others Contacts with Fermilab regarding geologic, geotechnical, and hydrogeologic information continue as they plan their accelerator upgrade. The U.S. Corp of Engineers boring logs for siting the original accelerator were made available to Fermilab. Many technical questions were answered by phone.

Educational Series Booklet on the Quaternary, Killey, staff Project planning took place early in the report period, and the first three chapters were drafted: "Introduction," "What Was the Great Ice Age?" and "Preglacial Landscape." Intended for a lay audience, the nontechnical report will explain the nature of the glacial landscape covering 90% of Illinois and discuss the value of the mineral resources in glacial deposits.

FUNDAMENTAL HYDROGEOLOGY

Groundwater Chemistry of the Mahomet Valley Aquifer in East-Central Illinois, Panno, K. Cartwright, Hackley, Liu Patterns of groundwater circulation in the Mahomet Valley Aquifer have been studied, using major ion chemistry and isotope geochemistry. Clearly defined geochemical regions with three distinct water types have been observed; contacts between the water types are abrupt. Data suggest that saline groundwater is migrating up from bedrock and entering the aquifer in the vicinity of western Champaign and eastern Piatt Counties. Analyses of groundwater sampled west of Champaign County indicate an enrichment of chloride and arsenic by several orders of magnitude.

Groundwater Chemistry of a Pristine Fen: Impact of Urbanization on Water Quality, Hensel, K. Cartwright, Panno The chemistry of groundwater samples from a wetland in northeast Illinois is being evaluated to determine long term effects of urbanization on the recharge area of three fens. The data indicate anthropogenic contaminants such as sodium, chloride, and sulfate (probably from septic effluent) are entering groundwater that feeds into the fens. The ISGS is attempting to determine threshold concentrations for these constituents, as they affect native vegetation. Shallow streams crossing the fens intercept incoming contaminants, and thus protect part of the fens.

PALEONTOLOGY/PALYNOLOGY

Paleontological Studies

Determination of the Paleontologic and Paleoenvironmental Setting of the Francis Creek Shale, Carbondale Formation, Middle Pennsylvanian of Western Illinois, Sroka, Jacobson The Francis Creek Shale is a gray shale that immediately overlies the Colchester Coal. Relatively low sulfur coal is often found associ-

ated with the thicker deposits of Francis Creek Shale. The data collected in this study will allow generation of new, detailed paleoenvironmental maps that are important for understanding the distribution of low sulfur coal. Primary work completed during this period consisted of field work to collect fossiliferous concretions. Some rare and important fossil forms have been found in these concretions. A paper reporting preliminary results was submitted for presentation at the GSA Annual Meeting in October 1992.

Salvage of an Exceptionally Preserved Silurian Soft-Bodied Fossil Biota, Mikulic (ISGS); Klussendorf (UIUC) The National Science Foundation awarded a 1-year grant to salvage a unique occurrence of soft-bodied Silurian fossils. The funds will be used to cover the cost of excavation and preparation of fossiliferous rock as well as to purchase equipment and hire temporary staff.

Although to date, these fossils have been found in only one quarry in Waukesha, Wisconsin, the rock unit (Brandon Bridge Member of the Joliet Dolomite) is present throughout northeast Illinois. Salvage of this biota and study of the environmental conditions under which they accumulated and were preserved will substantially expand our knowledge of the Brandon Bridge, a unit that presents quality problems for the aggregate industry of the Chicago area.

Taxonomic Study and Biostratigraphic Significance of the Mississippian Conodont Genus *Lochriea*, Norby, von Bitter (Royal Ontario Museum, Toronto) This study redefines the Mississippian conodont genus *Lochriea* and makes it more useful as an age indicator of rock units. Knowledge of the ages of stacked units can help in delineating geologic structures that may contain oil and gas. Several species, which will now be classified under this genus, have become important in several international time framework charts. The species were not well understood because the constituents of each species were misidentified.

Last year, a manuscript was completed, although at that time, some key ideas could not be proven and publication was delayed. Late last year, some new information was discovered; the original manuscript was modified and broken into two manuscripts; and the new information was presented at the North-Central GSA meeting in April 1992.

Palynological Studies

Major Floral Change at the Middle-Upper Pennsylvanian (Westphalian-Stephanian) Boundary in the Euramerican Coal Belt: Response to Climatic Change or Extraterrestrial Phenomena? Peppers Various explanations for the pronounced changes in Pennsylvanian coal-swamp floras are considered in this study. A faunal change was also associated with the floral changes, which have been traced from the Illinois Basin to the western part of the Midcontinent and eastward to the Appalachian Basin and Europe. The floral changes marked the end of the deposition of thick peat deposits that formed the major coal seams in Illinois.

Some asteroids probably hit the earth at about that time, although there is no evidence that the impact of any was great enough to have resulted in a sudden change in climate, as has been proposed. Such a climatic change has also been proposed as the cause of the later extinction of dinosaurs. The climatic change was presumably due to the northward movement of the enlarged land mass, major glaciation in the southern hemisphere, and reduction in atmospheric carbon dioxide, which affected the physiology of coal swamp plants. A paper based on this study was presented at a GSA meeting several years ago and recently submitted for publication to the *Journal of Paleogeography, Paleoclimatology, and Paleoecology*.

Major Middle-Upper Pennsylvanian Floral Change in Strata Other than Coal, Peppers It is already known which coal beds characterize the major change in coal swamp floras, but it is not known whether the floras changed gradually or abruptly between the last coal containing one kind of flora, and the first coal containing other floras. Also, it is not known which non-coal stratum marks the change and whether the floral change occurred at exactly the same time as the faunal change. Several outcrops were sampled in Illinois, Ohio, and Kansas; but only the sections in Kansas contain spores in strata between the two coals that characterize the floral change. Preliminary data indicate that the change occurs at a limestone, which would tend to discredit the suggestion that an unconformity and hiatus (when no deposition occurred) caused an apparent sudden change in floras and faunas.

Palynological Correlation of Major Pennsylvanian (Upper and Middle Carboniferous) Chronostratigraphic Boundaries in the Illinois Basin with Those in Other Coal Regions in the Equatorial Coal Belt, Peppers This manuscript was submitted for review to the Geological Society of America (GSA). The study is the most far-reaching and detailed palynological correlation of Pennsylvanian strata to date.

Distribution of Boghead Algae in Illinois Basin Coals, Peppers, Harvey The presence of boghead algae (*Botryococcus*) in the Illinois Basin was first reported by Kosanke in 1951 at a site in Fulton County. Since then, the alga has been observed at 43 sites in 11 coal beds. Although it is mostly rare, it is abundant or common in at least one site of eight different coal beds. It occurs in a rather short interval from the Reynoldsburg Coal to a coal equivalent to the Murphysboro Coal (late Morrowan to early Desmoinesian), and it is not known why it has not been found in younger, thicker coals that have been extensively mined. *Botryococcus*, which is still living today, occurs in fresh to brackish, flowing or quiet water. In this study, it has been found most commonly associated with the spore *Lycospora*, probably because lycopod trees grew in parts of the coal swamps that were flooded for at least part of the time.

Petrographic study of samples of some of the coals shows that the alga occurs in thin bands, and the bands can be classified as torbanite. Other layers are

cannel coal. Scanning electron microscope photographs of individual colonies reveal the morphology of the cells that are formed in pairs.

A poster will be presented in July at the 1992 meeting of the International Committee for Coal Petrography at Pennsylvania State University. A manuscript is also being prepared.

Palynological Correlation of the Dawson Springs Coal (Early Desmoinesian) and Equivalent Coals in the Illinois Basin, Peppers Spores have been used to correlate the Dawson Springs Coal of western Kentucky with the Buffaloville Coal of Indiana and the O'Nan Coal in southeastern Illinois. The coal seam, which has been extensively mined in western Kentucky, was also correlated with several coals in southern Illinois. The Buffaloville Coal had been miscorrelated with the Rock Island (No. 1) Coal in Illinois. The lower Middle Pennsylvanian coal is thus more widespread than previously thought. This study also shows that the limestone overlying the Dawson Springs Coal was miscorrelated with the Seville Limestone in Illinois. A report of this study is in review for the next issue of the Illinois Basin Studies series.

Palynological Correlation of Lower Pennsylvanian Strata Between the Illinois Basin and Forest City Basin of Missouri, Peppers As part of the cooperative studies of the Midcontinent Pennsylvanian Stratigraphy Working Group of the Society of Economic Paleontologists and Mineralogists, analyses were carried out on spores in coal samples from a core drilled in the Forest City Basin. Spore assemblages in the oldest coal beds indicate the coals correlate with the lower Tradewater and Caseyville Formations and are early Atokan and Morrowan in age. This is the first time the oldest Pennsylvanian strata in the oil-producing, Forest City Basin were identified as being as old as Morrowan. More samples are being studied to verify the results. A poster, co-authored by members of the Missouri Division of Geology and Land Survey, will be presented at the 1993 meeting of North-Central GSA in Missouri.

Palynological Study of Coal Samples for COGEOMAP, Peppers, Lowry Seven coal samples collected during mapping of the geology of the Makanda and Cobden Quadrangles were analyzed to identify their ages and to aid correlations of strata. One finding was that the Drury Shale and Sandstone are Atokan rather than Morrowan in age; and they should be placed in the Tradewater Formation rather than the Caseyville Formation.

Technology Transfer and Information Services
Curation of the Illinois State Geological Survey General Conodont Microfossil Collection, Norby Over the past 35 years, an important conodont microfossil database has been put together by several conodont researchers. This collection has never been properly curated, and some data are in danger of being lost. A general catalog of the slides from the approximately 260 stratigraphic sections has been made. Most

of these are from the Mississippian, but significant sections are from Silurian and Middle and Upper Devonian strata, and a few are from the Ordovician and Pennsylvanian. The next step will be to locate all stratigraphic and location data. As time permits, conodonts from each locale will be examined and notes will be appended to each section to provide key information to anyone using the collection.

GEOCHEMICAL INVESTIGATIONS

Geochemistry is the application of organic, inorganic, and analytical chemistry to geologic processes and materials. Through geochemistry, scientists at the ISGS conduct research into the processes that occurred or are presently occurring in the formation of minerals, including coal, petroleum, industrial minerals, base metals, and groundwater. ISGS research into the geochemistry of soils is also significant for projects in waste management and contaminant cleanup.

Projects of a general nature are described in this section of the report. This research contributes to understanding how bacteria act in the formation of petroleum and methane, and how certain native soil microbes degrade petroleum in contaminated soil. Geochemistry, as applied to specific research needs, is described in other sections of the report: Oil and Gas, Hydrogeology, Groundwater Protection, Waste Management, and Wetlands, Rivers, and Interior Lakes.

Geochemistry of Black Shales in the Illinois Basin: Review of Recent Literature, C.-L. Chou Systematic variations of carbon, pyritic sulfur, and degree of pyritization in the New Albany Shale (Devonian-Mississippian) relate to the availability of organic carbon and iron, and to the depositional environments. Shales highly enriched in organic carbon and trace metals may have been deposited in an euxinic environment. Pyrite was precipitated syngenetically near the sediment-water interface. Composition of relatively thin, black shale beds associated with Pennsylvanian coal-bearing strata may be related to enhanced biological activity in an upwelling, coastal environment. In November 1991, this paper was presented at the Eastern Oil Shale Symposium in Lexington, Kentucky.

Biogeochemistry

Oil-Spill Cleanup by Biodegradation, Salmon Soil microbes are capable of degrading petroleum after a spill. This research is intended to identify the microorganisms and mechanisms of biodegradation, which could lead to improvements in techniques for cleaning up oil spills. Oils and byproduct compounds will be extracted from contaminated soils by liquid chromatography, then the extracts will be analyzed. Soil microbes are being obtained from contaminated soils at an oil-spill site. Compound separation, fractionation, and analysis are to be completed at the ISGS.

Kinetic Isotope Effects Associated with Anaerobic Hydrocarbon Degradation, Risatti (ISGS); Bakel (Argonne National Laboratory) It has recently been

shown that n-alkanes (C_{12} to C_{21}) can be degraded by anaerobic bacteria. This confirms speculations that the distribution of n-alkanes in some petroleum reservoirs was a result of anaerobic bacterial degradation. To determine the magnitude of the kinetic isotope effect (KIE) associated with this degradation, we are determining the carbon isotopic composition of the residual alkanes from laboratory experiments. Knowledge of the KIEs associated with specific alkanes will be useful in oil-oil and oil-source correlations as well as in evaluating the extent of degradation and migration of an oil for both petroleum and environmental studies.

Tolerance of *Sulfolobus* sp. to Transition Metals, Risatti (ISGS); Miller, Risanico (Illinois State University) The tolerance of several species of *Sulfolobus* to various concentrations of sulfate soluble metals (Ni, Zn, Cu, Mo, Co, Mg) have been determined. The project was completed during the report period and a manuscript published by the Federation of European Microbiological Societies.

Acetoclastic Methanogenesis: Carbon Isotope Effects, Risatti (ISGS); Gelwicks (Merck Chemical); Hayes (Indiana University) Methane and acetate were collected and their stable carbon isotopic compositions determined from cultures of acetoclastic methanogens and experiments on lake sediment. The kinetic isotope effects were determined for the acetoclastic methane pathway and used to model the isotopic composition of the methane being produced in the lake sediments. The project was completed during the report period; a manuscript was written and informally peer-reviewed in anticipation of submission to the journal, *Applied and Environmental Microbiology*.

MINERALOGICAL INVESTIGATIONS

ISGS mineralogical research emphasizes methods of analysis and maintenance of a laboratory for studies of minerals, clay and related industrial minerals, and minerals that affect other ISGS programs (such as the effects of clay minerals on oil recovery). Mineralogical staff also review, advise, confirm, and consult with students and scientists throughout Illinois.

Mineralogical research and service support a wide range of projects within ISGS and assist the public, industry, government, and academic community. Mineralogical analyses inform landowners about the value of earth materials on their properties, identify changes in raw materials that affect recovery of mineral resources, and contribute to solution of environmental problems such as siting waste disposal facilities and isolating hazardous wastes. Upgrades of the computer operating system for the Scintag X-ray diffraction system, under the Illinois grant for improved oil recovery, have improved the quantitative analysis of minerals and synthetic substances.

In utilization studies during the past year, four models of the occurrence of clay resources were produced for the Paducah CUSMAP evaluation, new procedures were recommended for extracting oil, and



A

B



C

(A) Nelson Kawamura, graduate assistant, performs a specific gravity test in the rock mechanics lab. (B) Gary L. Salmón, chemist, injects an oil sample into a mass spectrometer. (C) David L. Moran, chemical engineer, and Jimmie D. Cooper, craftsman, conduct shakedown tests on the process optimization unit that produces high-surface-area hydrated lime.

improved methods were devised for the quantitative estimate of mineral matter in coals. Deposits of clay resources were located for Illinois industries. Several samples were analyzed to determine the initial composition of coal cleaning and coal burning wastes, and to monitor changes that occur during simulated disposal of the wastes. Samples were also analyzed for Quaternary framework and mapping efforts. A cooperative study with French researchers led to a new model of the thermal and burial history of the Illinois Basin.

Mineralogical research on clay minerals in soils has recently been undertaken to reconstruct the paleogeography and paleoclimates of ancient soils, predict the suitability or capacity of soil materials for the isolation of hazardous wastes, indicate areas of geotechnical hazards or stability, and evaluate soils for clay products, pond liners, and various agricultural uses.

Discovery of berthierine in native American artifacts from northwestern Illinois led to studies of the origin and mineralogical structure of this rare clay mineral and changed the archeological interpretation of Paleo-Indian trade networks 1,800 to 5,000 years before present. The kaolin deposits and oolitic iron oxides associated with this berthierine also have been investigated as resources and to refine geological descriptions of the strata in which they occur.

Research

Improved X-Ray Diffraction Procedures, Hughes, Hurley, Moore Improved quantitative analysis of the mineralogical composition of rocks and minerals is the focus of this investigation. A three-step method for determining the clay mineral content of sedimentary rocks is being tested. This determination is critical for accurate as well as precise analyses of minerals from diverse sources such as coal seams, construction sites, industrial clay and shale deposits, oil and groundwater reservoirs, and waste disposal sites. A computer program has been designed to combine computer-modeled spectral "fingerprints" of each mineral with chemical data and produce comprehensive analyses. Goals for next year are to complete and test the program.

Quaternary Geology by Mineral Composition, Glass, Moore, Hughes, Wang (ISGS); Reynolds (Dartmouth College) The mineral composition of Quaternary deposits and associated soils is being used to reconstruct their depositional history. Also under study are the mineralogical characteristics that distinguish wet soils formed in place from eroded soils deposited in wetlands.

Mineralogical analyses are being performed for four mapping and framework studies. Analyses for Hong Wang's Ph.D. research will assist in reconstruction of ice-age climates by determining the oxygen and hydrogen isotopic composition of a clay mineral that forms only during contemporaneous soil formation.

Native American Artifacts Made from Berthierine in Whiteside County, Illinois, Hughes, Moore (ISGS); Berres (UI-UC); Farnsworth (Illinois State Museum) Berthierine, a rare clay mineral with a structure similar

to kaolinite, has been found to be the raw material for 1,500- to 5,000-year-old Native American artifacts from northwestern Illinois. A sample found in the Neda (?) Formation (Ordovician) proves that the raw material for these artifacts came from Sterling, Illinois, rather than near Portsmouth, Ohio, as had been assumed. An Illinois source changes the perception of the value placed on these artifacts by aborigines and of their dispersal through ancient trade networks.

A second site near Albany, Illinois, was investigated to see whether materials at this site came from a local source or the deposits near Sterling. Because berthierine from this area is a valuable scientific reference, efforts are being made to find larger deposits of berthierine within the Neda. An analysis of the amount of ferrous and ferric iron in our purest berthierine sample has been obtained from the UI-UC Department of Agronomy. The analysis will be used to refine the crystal structure of this berthierine.

Technology Transfer and Information Services New Illinois Pipestone Revises Hopewell Trade Routes, Hughes, Moore (ISGS); Farnsworth (Illinois State Museum); Berres (UI-UC) The source of clays used by Native Americans, as reported above, the importance of the clay material berthierine as a standard reference material, and its possible impact on modern-day resource issues in Illinois were discussed in a paper presented in various formats. A poster was presented at the annual meeting of the American Association for the Advancement of Science in Chicago. Talks were given at the ISGS and the annual meeting of the Association of Illinois Quaternary scientists (ILQUA).

Mixed-Layered Kaolinite/Expandables: Occurrence and Rates of Formation in Quaternary, Mississippi Valley Loesses, Hughes, Moore, Follmer (ISGS); Grimley, Johnson (UI-UC) This paper was presented at the annual meeting of the Clay Mineral Society of America in Houston, Texas. The poster showed that this clay mineral is abundant in modern soil and at least three major paleosols at Thebes, Illinois. The modern and ancient occurrences allow a comparison of climates and rates of weathering during the present and last two warm periods between major advances of glaciers. Because the warm periods between the advances of the major glaciers seem to have been similar in the climatic sense in the Midwest, and because the parent materials for these soils are similar, the amount of mixed-layered kaolinite/expandables in modern and ancient soils allows an estimate of the duration of weathering.

Nature, Detection, Occurrence, and Origin of Kaolinite/Smectite, Hughes, Moore (ISGS); Reynolds (Dartmouth College) This paper, published as part of a special monograph of the Clay Mineral Society of America, demonstrates that the clay mineral kaolinite/smectite is much more widespread in modern and ancient soils than once thought. Methods of identifying the mineral, comments on its place in the economically important, kaolin clay mineral group, and suggested procedures for nomenclature appear in the report.

Qualitative and Quantitative Analysis of Clay Minerals in Soils, Hughes, Moore, Glass Prepared for publication in a monograph of the Agronomy and Soil Science Societies of America, this chapter summarizes useful methods for the investigation of modern and ancient soils and includes examples of the application of the methods at several sites within Illinois.

COMPUTER RESEARCH

Computer Research includes development and optimization of the software and hardware components of the computing environment to support ISGS research and service. ISGS computers and related hardware include a Prime 9955 minicomputer; Sun, Vax, and Silicon Graphics workstations; pen and electrostatic plotters; and film recorders, digitizers, graphics terminals, and other devices. Workstations have replaced the Prime 9955 minicomputer, which was disconnected on July 1, 1992. Devices are linked via an Ethernet network within the Natural Resources Building and via leased phone lines to ENR in Springfield. The UI-UC optical fiber network and Internet provide links to major computing centers around the nation.

The Geologic Mapping and Digital Cartography Section continues to construct and maintain tabular and graphic databases, apply specialized software to geologic problems, integrate computer systems, assist staff to evaluate software and hardware, consult on computer usage, and develop the data resources of the Illinois Geographic Information System (GIS).

Programming and Data Entry Research

Arc Macro Language for GIS, Pool, McLean, Denhart Several abandoned mine land (AML) programs were developed and refined for GIS applications. These include HYPSO, PINFO, GETQUAD, and SCALEBAR. HYPSO gives the Sun Sparcstation user a menu interface for the editing and attributing of scanned digital line graph (DLG) hypsography (contour line) data. PINFO provides a menu interface that allows maps to be created and printed and data to be viewed by the ISGS and the Illinois Department of Mines and Minerals staff using the AML Lands Unsuitable Mine Permit database. GETQUAD is a program within the ARCEDIT subsystem that initializes a digitizing session by allowing the user to select quadrangles. GETQUAD sets up the orientation of the coordinates, draws the quad boundaries, and adds user-specified annotation. SCALEBAR within the ARCPLT subsystem allows custom creation of graphic scale bars for maps. (At ESRI's annual meeting, Robert Pool was awarded second place with the SCALEBAR program in the GIS tools competition.) Ongoing projects include maintenance of spooling and accounting software to manage ISGS color plotters and specialized commands to customize the GIS environment for ISGS users.

Technology Assessment

GIS Hardware Assessment, Pool, Denhart, McKay Working with GIS staff, ISGS staff have evaluated and acquired a terminal server that provides a serial line to

the Ethernet interface to allow former users of the Prime computer to continue using GIS software without changing their local terminal environment. Staff evaluated and purchased a Sparc 670 server, a 100 Mips computer that now provides high-speed performance for GIS users. They also acquired and tested a Microtek flatbed 400 DPI optical scanner for scan-digitizing of maps, other graphics, and photos.

Software Assessment, Pool, Witzany, McKay Staff are evaluating soft-PC and other software that will expand the functionality of workstations to include word processing and other applications usually run on a PC. Implementation of soft-PC for staff currently using both workstations and PCs could eliminate some PC hardware. Also, staff analyzed Notebook and Referee software for compiling and managing bibliographic data for the Critical Trends Assessment Project.

Computer Systems

Computer Hardware Acquisition The ISGS continues to acquire computer GIS workstations and connect them into the Natural Resources Building Ethernet network. The ISGS network includes 15 Sun workstations, one Sun 670 Server, four DEC workstations, and two Silicon Graphics workstations that communicate and share data. The Sun workstations replace the Prime 9955 computer, which was disconnected July 1, 1992. The Vax systems are used for mapping and data management for the Improved and Enhanced Oil Recovery Program jointly sponsored by the U.S. Department of Energy and the State of Illinois.

Workstation Software Environment The ISGS has upgraded to ARC/INFO version 6.0.1 on its Sun Sparcstation computers; this is the latest available version of ARC/INFO. On the Silicon Graphics Iris workstations, the ISGS is running Dynamic Graphic's Geologic Modeling Program (GMP) and Stratamodel. The GeoQuest mapping software and Oracle relational database software are installed on Vax computers.

Technology Transfer and Information Services
Digital Data Sales, McKay, Denhart, L. Smith Sales of digital data under the Natural Resource Information Fund are continuing. County agencies (for example, the Supervisor of Assessments for Saline County), educational institutions (the departments of Technology and Mining Engineering at Southern Illinois University), and private industry (Northern Illinois Water Corporation) have purchased Public Land Survey Grid data. The ISGS receives approximately two phone calls per week concerning the availability of digital data.

Map of Wells and Borings in Illinois, McKay, Denhart A 1:500,000-scale map showing all well locations of record in the state is in administrative review. The status of each of the more than 316,000 wells is depicted by a color symbol. Drilling trends in the state become apparent, as the map shows concentrations of oil and gas wells in the southeast, water wells in the northeast, and coal test borings in the south and west.

The map will be available through the ISGS Open File Series. Color copies will be produced on the electrostatic plotter to fill requests.

USGS Work-Share Agreement for Digital Topography of McLean County, McKay, McLean, Abert, Pool, Riggs, Smith, Stiff, Taylor, Witzany The ISGS and USGS entered into a cooperative arrangement to compile a digital, topographic database of McLean County. The ISGS proposed the idea as an alternative method of compiling topographic databases to support county-level mapping. The USGS provided the ISGS with digital data scanned from the hypsography layers for thirty-three 7.5-minute quadrangles in McLean County.

ISGS staff are correcting contour line errors introduced during the scanning process and assigning elevation codes according to USGS standards. Computer processing of digital elevation for 13 quadrangles has been completed and delivered for evaluation to the USGS Midcontinent Mapping Center in Rolla, Missouri. The data will become part of the digital line graph information and made available by the USGS as part of the National Digital Cartographic Database.

Automation of a Bedrock Topography Map of Illinois, Pool, Herzog, Kempton, Stiff, McKay (ISGS); Kupperman, Warner, Avery (USGS) The ISGS and USGS Water Resources Division in Urbana cooperated in the production of an updated, 1:500,000-scale, bedrock topography map of the state. Original mapping by the ISGS and USGS was redrafted, then scanned using digital equipment at the USGS National Mapping Division in Rolla, Missouri. The data were transferred to ISGS computers for editing and coding. There will be two final products: a digital, bedrock topography coverage and a printed map.

SCIENTIFIC SUPPORT SERVICES

Maintaining centralized laboratories equipped with state-of-the-art analytical instruments and computers and staffed by qualified professionals is the most cost-effective method of providing scientific support to ISGS researchers. The service laboratories and scientific support units are used not only by ISGS staff, but also by researchers throughout Illinois. Emphasis is placed on quality assurance/quality control (QAQC); some ISGS laboratories have achieved international reputations for their high quality data and research.

Quality Assurance/Quality Control

Ad Hoc Committee on Sample Data Management, Harvey, Dreher, Denhart, Chaven, Hensel, Su, Goodwin Procedures for entry of descriptive information on tested samples from Illinois deposits into a new database were established for each ISGS laboratory. The Tested Samples Database is linked to longstanding procedures of the ISGS for managing requests for new analyses of samples. One person in each ISGS laboratory has been assigned to coordinate and check the accuracy of the sample descriptions before they are entered into the database.

Analytical Chemistry Services

During the report period, analytical chemists in the Geochemistry Section analyzed samples from 16 research projects, plus individual samples from various sources around the state. Analyses were needed for studies on diverse topics: enhanced oil recovery, yard waste composting, wetlands, correlation of cores from the Maquoketa formation, oils from the Ordovician Trenton Formation, the Illinois Basin Coal Sample Program, ecology of a pristine fen, field study of transit time through a compacted clay liner, use of fluidized-bed coal wastes in reclaiming coal slurry solids, development of high-surface-area hydrated lime, sediments in the Grand Calumet and Illinois Rivers, chemical composition of Illinois soils, characterization of the surface properties of Illinois Basin coals, validation of analytical methods for pesticides by an interlaboratory comparison, atrazine loadings in streams, surfactant effect on sorption and leaching of atrazine in sandy soils, and solid-phase extraction for the determination of pesticides in soils.

Single samples or small groups of samples were analyzed for the Kane County Health Department, Lake County Health Department, U.S. Army Corps of Engineers, USGS, and the UI-UC Department of Mechanical Engineering. In total, 5,390 samples were analyzed, and 31,248 determinations were made on the samples.

Analytical Chemistry Method Development: Wetlands, Cahill Knowing the local and regional water chemistry is critical in wetland research. Before any trends in water and sediment chemistry can be determined, sampling and analytical techniques must be evaluated and standardized. This effort began this year with the purchase of sampling and field analysis apparatus. Parameters being evaluated include pH, conductivity, nitrate, iron, phosphate, ammonia, sulfide, cyanide, dissolved oxygen, copper, chloride, and alkalinity. Preliminary results show good agreement between laboratory and field measurements. An equally important task has been training staff from the ISGS and Illinois Natural History Survey (INHS) on the choice of parameters to measure, and the proper procedures to follow in the field.

Analytical Chemistry Method Development: Lead-210, Cahill Work began on modifying and updating procedures for determining lead-210. An alpha spectroscopy system was assembled, methods were established, and standard solutions were received. The procedure will be used to confirm cesium-137 results and extend the time frame for estimating sedimentation rates back to 100 years before the present.

Isotopic Geochemistry Services

Isotopic Analysis Service Laboratory, Liu, Hackley, Hwang, Cao, Donnals In the report period, carbon and oxygen isotope analyses were completed on 792 samples; sulfur isotope analyses were performed on 620 samples; deuterium-to-hydrogen ratios were determined for 545 samples; and nitrogen isotope

analyses were carried out on 481 samples. About 15% were for QA/QC and standardization purposes.

Projects supported by isotopic analysis services included general Quaternary research, geochemical and isotopic characterization of a buried bedrock valley aquifer (Mahomet Aquifer), application of environmental isotopes to landfill monitoring studies, development of methods for δD determination of soil clay hydroxyl, stable sulfur isotope geochemistry of Illinois coals, behavior of sulfur and chlorine in coals during combustion and boiler corrosion, sulfur removal from high sulfur Illinois coal by low temperature perchloroethylene (PCE) extraction, Paleodietary study of prehistoric people in north America (for UI-UC), and archaeologic evaluation of prehistoric Indian sites in Illinois (for UI-UC and Illinois Department of Transportation).

About 65% of all services performed in the laboratory during this report period were funded through various research projects.

Radiocarbon Dating Laboratory, Liu, Wang, Coleman Radiocarbon (^{14}C) age determinations are provided as a service by ISGS to both the geological and archaeological community. During the report period, 130 radiocarbon age determinations were performed on regular samples for scientists throughout Illinois; 50 radiocarbon measurements were conducted on groundwater, landfill methane and CO_2 , and landfill leachate samples in support of the landfill study.

About 68% of all samples processed in the laboratory during this report period were funded through various research projects.

X-Ray Diffraction Services

Hughes, Moore The Scintag X-Ray Diffraction (XRD) instrument was upgraded during the year to give new flexibility in measuring XRD peak areas and allow for the electronic transfer of peak intensities. An estimated 1,500 XRD analyses were run for clay minerals and 380 were performed for determinations of other minerals. The analyses were run for 41 different projects; about 15% were for QA/QC.

Round-robin determinations overseen by the USGS were made on the low temperature ash of an Illinois and a western coal; determinations based on two methods gave similar results. These similarities and the approximately 0.99 correlation coefficient between XRD and weight loss measurements of total carbonate minerals in oil reservoir samples show that improvements in analytical procedures are paying large rewards in increased accuracy and precision.

Other Analytical Services

Low Temperature Ashing Laboratory Service, Lowry Sixty-five samples for at least six different projects were processed through the lowtemperature ashing (LTA) laboratory. Twenty-two samples were ashed for

further chemical and mineralogical analyses, and 43 samples were etched for SEM-EDX analyses. One LTA unit was adapted for use with a Quadrople Gas Analyzer for real time analysis to determine the composition of the off-gases emitted when coal samples are oxidized at low temperatures.

SEM Laboratory Service, Lowry, Harvey, Seyler, Demir The scanning electron microscope (SEM) was used extensively on three projects: Improved and Enhanced Oil Recovery Methods and Concepts (Seyler), Characterization of Organic Sulfur in Macerals and Chars (Harvey and Demir), and Boghead Algae (Peppers, Harvey, and Lowry). The laboratory also served other projects: Sulfur Removal from High Sulfur Illinois Coals by Low Temperature PCE Extraction (M. Chou), Carbonation as a Binding Mechanism for Coal/Calcium Hydroxide Pellets (Rapp), and others.

During the year, the SEM was used by three ISGS operators for approximately 578 hours to characterize 145 samples. The laboratory is jointly supported by the ISGS and INHS.

Geotechnical Services Unit The Quaternary Materials Laboratory has been transferred to the Engineering Geology Section and renamed the Geotechnical Services Unit. As a consolidation of three laboratories, the unit is now responsible for QA/QC procedures as well as particle-size analyses, rock strength testing, and testing the physical properties of soil materials.

Computer Services

Riley Microcomputers (PCs) are important tools for nearly all ISGS business, from the task of collecting raw data in the field to the processing of reports. To ensure efficient use of PCs, this support service responds to questions and problems concerning purchasing and installing equipment, recommends software and hardware for specific tasks, and advises on computer operation and repair. In the report year, 630 computer tasks were initiated and 611 completed.

Laboratory Safety

Safety Committee, Dreher, others A Chemical Hygiene Plan for laboratories at the ISGS was written and distributed to all staff members who work in laboratories. The Chemical Hygiene Plan was written in response to the Occupational Safety and Health Administration's rules for Occupational Exposure to Hazardous Chemicals in Laboratories, otherwise known as the OSHA Laboratory Standard.

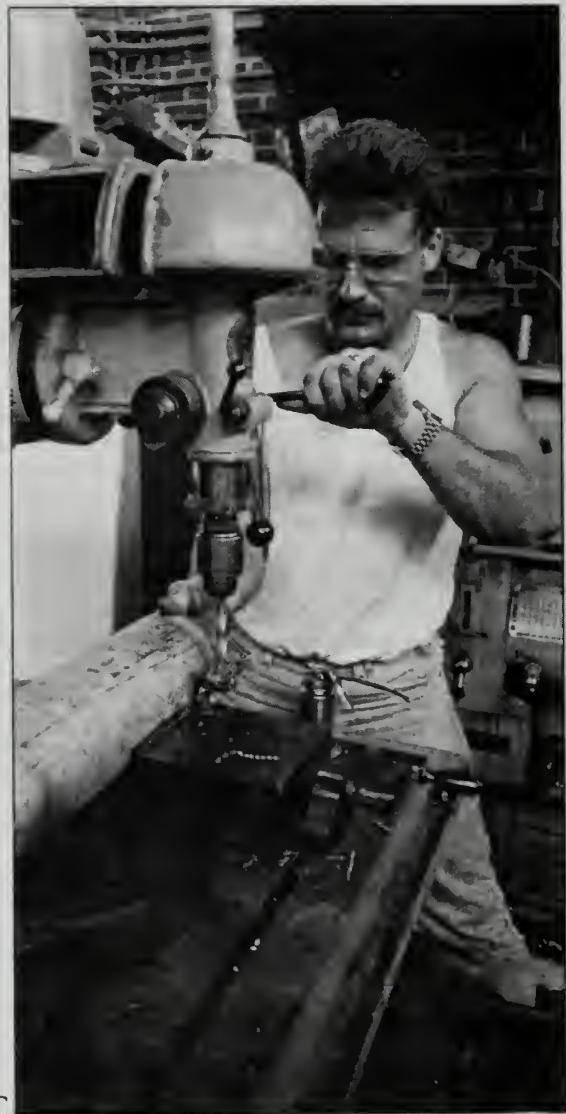
The Chemical Hygiene Plan outlines responsibilities of the safety committee, the chemical hygiene officer, and ISGS management and employees; standard operating procedures for laboratory safety; methods for controlling chemical exposure; and what to do in case of an on-the-job injury.



A



B



C

(A) Staff members of Samples Library reshelfe cores used in research for the Improved Oil Recovery Program. (B) Graphic artists Michael Knapp and Pamella Carrillo discuss artwork for a publication with geologist B. Brandon Curry (center). (C) Timothy C. Young, driller, constructs protective well casing on the drill press for the IDOT wetlands project.

TECHNICAL AND ADMINISTRATIVE SERVICES

Vital operating functions support ISGS research and service programs: budgeting, accounting, and financial reporting; preparing and monitoring of contracts and grants; counseling, advising, and timekeeping for human resources; cataloging, searching, and locating library references; receiving and distributing incoming mail, commodities, and equipment; processing orders and shipping publications, maps, and other materials; maintaining the Information Office and the Illinois Affiliate Office of the National Earth Science Information Center; conducting public field trips, responding to various inquiries, and distributing educational materials; overseeing media and legislative relations; fabricating, maintaining, and repairing scientific, office, automotive, and other equipment and instruments; arranging changes in telephone programming and billing; providing editorial, graphic, duplication, and other publications services; and planning and supervising new construction and building renovations.

The Geological Records Unit and the Geological Samples Library also provide vital technical support to research and service at the ISGS and to the public and private sectors. The documentation of Illinois geology maintained by these two units and the Reference and Map Library is the core of ISGS activities and a basic source of information for private industry, government agencies, and the general public.

BRANCH OFFICE

Peters Secretarial services are provided for the Technical and Administrative Services Branch; telephone system/credit card changes and billing are provided for all ISGS staff. Serving as the interface between the ISGS and various departments of the University of Illinois, staff handled requests for maintenance by the University Physical Plant and made reservations for University vehicles. They also handled outside requests for loan copies of out-of-print ISGS publications. Because of the severe budget crunch, the Branch Office provided part-time clerical assistance to the Human Resource Office, the Hydrogeology Research Laboratory, the Educational Extension Unit, the Public Liaison Officer, and the Contracts and Grants Office.

Responsibility for telecommunications (credit cards, moves and changes, phone numbers on contract, and jacks hooked into the Ethernet system) rests with this office. In addition to routine reporting of troubles with telephones, staff update the telephone list.

Maintenance problems for the Natural Resource Building and Garage, Annex, and Applied Lab were reported by this office to the University's Physical Plant. For the Savoy offices, problems were reported to the University Office of Facility Planning.

BUSINESS AND FINANCIAL SERVICES

Griest During this report period, the Business and Financial Services Unit (BFSU) focused on budgeting, cutbacks, replacement of two key staff members, and

reorganization of contract accounting work assignments. BFSU also prepared numerous budget and reduction scenarios, helped design a workable reduction plan, and assisted Management Committee members in presenting options for necessary cuts to meet the FY92 reserves and FY93 funding reductions.

Throughout the year, despite unusual turnover in the Unit, BSFU undertook to fulfill its fundamental responsibilities of budgeting, purchasing, vouchering, and accounting for all funds appropriated and allocated by the State to the ISGS, as well as those of purchasing, vouchering, accounting, and providing budgetary support for ISGS-sponsored research funds.

A redistribution of responsibilities occurred to provide for greater independence of staff and thus make the unit more versatile.

GRANTS AND CONTRACTS

Young The Grants and Contracts Office (GCO) staff assisted the research staff by identifying new funding opportunities and offering guidance in all phases of proposal development. By reviewing proposal budgets and other documents, the GCO helped ensure that proposed research and service projects comply with both internal ISGS requirements and with the policies, guidelines, and regulations of the sponsoring organization, the University of Illinois, and the Board of Natural Resources and Conservation.

Summary data on the status of pending proposals and active contracts were compiled and reported on a monthly basis to the Chief, the Director of the Illinois Department of Energy and Natural Resources (ENR), and others. Supplementary data compilations and special reports concerning grant and contract policy issues and other matters also were prepared upon the request of the Chief or the Branch Chiefs.

As the primary contact with the University's contract administration, the GCO helped to maintain liaison with the University, routed inquiries about financial or programmatic matters to the appropriate ISGS administrative unit or staff member, and coordinated responses. Whenever possible, the GCO created "boilerplate" documents, such as proposal budget forms, standard agreements, and requests for contract change forms in a word-processing format and made diskettes available for use by research staff.

GCO staff participated in the Campus-Wide Research Coordinators/Administrators Group at the University of Illinois at Urbana-Champaign (UI-UC). The mission of this group is to (1) enhance communication within the UI-UC campus on issues of interest in research administration, (2) benefit UI research and improve the research infrastructure of UI-UC, and (3) provide the opportunity for professional development in the field of research administration. Association with this group has broadened and enhanced relationships with the research administrators of UI-UC. These contacts have proven valuable in cooperative projects with University staff.

HUMAN RESOURCE OFFICE

Cunningham The Human Resource Officer attended an Americans with Disabilities Act (ADA) training seminar held in Chicago in the fall of 1991. When UI-UC sponsored an ADA seminar, presented at the Krannert Center for the Performing Arts, the HRO coordinated ISGS participation. HRO staff also coordinated ISGS participation in two sexual harassment seminars that were sponsored by UI-UC and attended by 50 ISGS managers, supervisors, and principal investigators. Various other UI Staff Development Seminars were attended by 22 ISGS staff.

Of the 57 searches made during FY92, 54 were conducted on behalf of contracts and grants; 30 were for hourlies; and three were for state-funded vacancies. Six of the 54 contract searches were cancelled, and the HRO staff processed the paperwork for 51 new staff members. A total of 846 applications were received in response to position announcements; all were acknowledged by letter.

The HRO processed paperwork for F-1, J-1, and H-1B Visas. One permanent residency was finalized and paperwork initiated for another permanent residency, in compliance with immigration laws that changed considerably in October 1991.

Four seminars were presented by the Human Resource Assistant during the annual Benefits Choice Period; the result was 47 insurance transactions for state-funded staff. Insurance files for 40 state-funded, ISGS staff members were transferred to UI-UC, and six were transferred back to ISGS from UI-UC. With the recent installation of an Ethernet, HRO is now making benefit changes through direct online access to Central Management Services (CMS) in Springfield. Online training has been completed for the two full-time HRO staff members.

Additional paperwork processed by the HRO staff included 150 Status of Participation Reports to the State Universities Retirement System, 53 employment verifications, 62 tax cards, 30 probationary evaluations, 35 tuition and fee waivers, 245 medical insurance cards, 70 dental cards, 6 workers compensation reports, and for the months of June and July alone, 166 Contract Appointment Requests. New photo IDs were issued by ENR; more than 270 were processed for the ISGS staff in a 2-day period. Also processed were 148 identification cards issued by UI-UC.

LIBRARY AND MAP ROOM AND PUBLIC INFORMATION UNIT

Krick The Unit supports ISGS staff by consulting on references and sources of information, obtaining materials from libraries and other sources, and providing mailing information and services. Also, by duplicating materials, making them available for sale, and exchanging with libraries around the world, the Unit ensures that ISGS maps and publications reach the public.

Information Office

As the center for public inquiries, the Information Office handles general questions about the ISGS. More

detailed questions are referred to appropriate scientists. Staff handle over-the-counter sales and process orders for ISGS maps and reports and USGS maps of Illinois. Bookkeeping for sales, maintaining gift and exchange lists, and responding to claims are also handled here.

In October 1991, the Information Office began using the Great Plains Accounting System for sales and inventory. Staff were trained and report formats developed; a phase of debugging and enhancement is ongoing. The Great Plains Accounting System provides efficient bookkeeping and inventory operations.

Mail Room

The Mail Room is the central receiving and distribution point for the ISGS. Staff handle incoming and outgoing shipments, receive and sort all mail, process bulk mailings, and order and stock office supplies. Orders for maps and publications are filled and shipped from this office. Inventories of ISGS publications and USGS maps are maintained to fill orders and distribute publications to staff.

In February 1992, the Mail Room began using a new Pitney Bowes USPS/UPS scale that weighs pieces up to 100 pounds; it can also count identical pieces. Comparative "shopping" for the most economical shipping cost has become more efficient with this scale because it displays 1st, 3rd, and 4th class as well as library, foreign, and UPS rates. Use of UPS has grown significantly for this reason. The new system also decreases the UPS paperwork.

Greater use of the USPS permit imprint also decreased cost and increased efficiency. The imprint, which is printed directly on pieces whenever appropriate, eliminates the need to run items individually through the postage meter and also allows fractional postage charges rather than rounding up charges to the nearest penny.

Mail Room Operating Statistics

	FY91	FY92
Distributed		
ISGS publications	24,517	20,277
ISGS maps	3,244	2,376
ISGS blueline maps	2,990	2,214
USGS maps	21,625	22,371
Orders filled	7,320	5,065
Shipped		
Pieces mailed	60,934	32,564
Pieces sent UPS (Feb 1992-)	-	513
Pieces sent with permit imprint	1,347	17,300
Costs		
Mailing	\$26,210.00	\$22,227.19
UPS (Feb 1992-)		2,476.99
Permit imprint	164.87	2,699.64

Earth Science Information Center

The ESIC provided geodetic and general cartographic information in response to 510 requests from the public

A major responsibility is maintaining inventory of USGS topographic maps. New or revised editions of 29 maps in the 7.5-minute, 1:24,000-scale quadrangle series were released this year; another 99 are in preparation in two separate USGS projects. Topographic maps are available for 46 of the 47 quadrangles in the 30×60-minute series (1:100,000 scale). Completion of this series is expected in early 1993. In the 1:100,000-scale county map series, 59 maps have been published.

Duplicating Services

All ISGS materials, except four-color items, can be reproduced in the ISGS Duplicating Shop. The workload continues to be consistently heavy, often requiring the help of students and other staff in the branch. Impressions made this year totaled 1,560,715.

Recycled paper is used for duplication, whenever possible. As nonrecycled supplies decrease, recycled paper is purchased. All ISGS publication series, except Bulletins and *Geonews*, are produced on recycled paper.

Library and Map Room

Reference services are provided to ISGS staff and visitors. Journals, acquisitions lists, and other materials are routed to notify staff of new publications and developments in their fields. Citations are verified and completed, bibliographies prepared, online literature searches run, and articles, books, and reports located and borrowed. Instruction in the use of the ISGS library, the University of Illinois libraries, and the Illinet Online computer system is available. Interlibrary loan requests received through the Lincoln Trail Libraries System and other libraries are filled.

Library Operating Statistics

	1990-91	1991-92
Acquisitions—total	1388	1086
Books	123	155
State documents	533	346
U.S. documents	346	429
Miscellaneous documents	221	156
Manuscripts	42	13
Maps	123	270
Items withdrawn—total	2531	172
Serials titles and newsletters received	299	321
Library circulation—total	2772	2649
Books, documents, serials, misc.	1899	1973
Maps	608	478
Field notebooks, photos, slides	73	71
Interlibrary loans (lent)	192	127
Journal routing		
Periodicals routed	1614	1560
Tables of contents routed	484	521
Interlibrary loans (borrowed)—total	768	996
• UI-UC libraries	360	426
• Lincoln Trail Libraries System	213	337
• direct from other libraries	195	230
Reference questions	1904	2602
Online bibliographic searches	49	25
Visitors	181	395
Outside phone requests	258	264

Reference questions and interlibrary loans increased dramatically, largely because of work on two major projects: (1) Critical Trends Assessment and Desulfurization, and (2) Utilization of Coal Combustion Residues. The library portion of these projects required multiple literature searches, citation verification, and retrieval of materials.

Computer print capabilities were improved with the addition of a laser printer. Access to the network through Ethernet is also available.

Map cataloging is underway again since the completion of a project to review and revise the catalog for more consistent access points.

PUBLIC LIAISON

Muckensturm A major thrust of Public Liaison is apprising decision makers and the public of ISGS research and service. Also, a concerted effort is being made to inform governmental officials at all levels—municipal, county, state, and federal—of the ISGS role in strengthening the state's economy and improving the quality of life for Illinois' citizens.

Regional planners were contacted to inform them of the geological expertise as well as vast databases available at the ISGS to help with planning and making prudent, environmentally sound decisions about siting new facilities or locating and developing natural resources. To this end, the Public Liaison Officer visited grassroots officials and community leaders; city, county, and regional planners, engineers, and zoning officers; legislators and their staff; and departments of state government to inform them about ISGS efforts to address a multitude of complex environmental and resource-related issues facing the state.

The unit also promoted a better understanding of the ISGS and its work as well as closer relations with its many constituencies: the Illinois delegation in Washington, D.C., the Illinois General Assembly, the Illinois Department of Energy and Natural Resources (ENR), other governmental agencies, the Nature of Illinois Foundation, news media, industry, target groups, and the public.

News of research and service was disseminated through a mini-annual report written especially for the public, meetings with special interest groups, articles for magazines and newsletters, letters and visits, news releases and editorial commentaries, fact sheets, reports, brochures, and exhibits.

Monthly reports on major research were sent to the Director of ENR for incorporation into reports to the Governor's subcabinets on Economic Development and Natural Resources.

Articles were prepared for *Nature of Illinois*, the magazine of the Nature of Illinois Foundation; the newsletter of the American Association of State Geologists; *Illinois Resources*, the ENR newsletter; the annual report and brochure produced by ENR; and the State's Bluebook.

The media were teamed with scientists working on specific issues. The unit also arranged interviews for special news features. News releases were prepared on

Table 1. Final Projects*

	<i>1988-89</i>	<i>1989-90</i>	<i>1990-91</i>	<i>1991-92</i>
Bulletins	0	0	1	1
Circulars	2	1	2	2
Environmental Geology series	3	3	6	4
Cooperative Groundwater Reports	2	1	0	3
Illinois Mineral series	2	2	3	2
Illinois Petroleum series	2	1	2	2
Illinois Mine Subsidence Research (limited series)	1	0	0	0
Illinois Basin Studies (Consortium)	-	1	0	1
Special Report (new series)	-	-	-	† 1
Guidebook series	0	† 2	† 2	1
Contract/Grant Reports (discontinued series)	2	5	-	-
Open File Series (new series)		-	7	22
Illinois Scientific Survey Joint Reports	0	2	0	0
<i>Total of original reports in ISGS series</i>			16	24
Reprints of outside publications	18	17	19	14
Educational Extension Field Trip Guides	4	4	4	4
Papers, book chapters, misc. text (>5 p)	22	15	21	15
Large format maps, cross sections, strat columns**	3	0	12	16
Posters, displays, major slide programs	24	25	20	21
Brochures, fliers, announcements of pubs	15	14	18	17
Administrative, miscellaneous, and Geonews	12	5	5	5

* tally of projects (published or unpublished) without calculation of size and complexity.

** includes 3 Quaternary maps, 4 Illinois Basin cross sections, 5 plates from C551, and 4 maps from Coop 13; excludes IGQs.

† The Special Report and the guidebooks printed in 1989-91 were reprints of earlier publications. This year's Guidebook 24 is an original work.

personnel changes, awards, and special recognition; geological science field trips; the enhanced oil recovery program; mineral potential in the Midcontinent; radon; clean coal technology; coal feedstock; a deep source for oil; and new ISGS publications. Informational outreach also included displays hosted at the Illinois State Fair and two statewide meetings of county officials.

PUBLICATIONS, GRAPHICS, AND PHOTOGRAPHY

Wolf Publication output of original reports in ISGS series (table 1) grew from 16 in 1990-91 to 24 in 1991-92. The most significant rise in production was shown in a new area—the Open File Series. The utility of the OFS, now in its second year, seems well established for publications that will not be mass produced because of limited demand, prohibitive costs, or continual updates. The Unit's production of reports, maps, and cross sections for the series (table 1) jumped from seven in 1990-91 to 22 in 1991-92.

Large format graphics (table 2), each requiring 60 to 150 hours to complete, set the schedule for graphics production during the winter of 1991-92. Last year's tally of 12 maps and cross sections increased this year to 16: three maps of Quaternary deposits, four cross sections of the Illinois Basin, four maps of the Mahomet Bedrock Valley, and five plates for the forthcoming circular on the Davis and Dekoven Coal resources.

Demand for the photographer's skill with a camera in the field, lab, and studio continued to grow, as reflected by the increase from 4,800 to 8,280 shots taken over the last 3 years (table 2). About one-half of this total is color slides and prints; the other half is for black and white prints. The photographer makes contact prints of all black and white exposures, but prints up only those selected for a specific purpose. The current practice is efficient and cost effective. Also, all contact prints and negatives are filed for future use or transfer to the ISGS photo archives.

Restructuring the typesetting operation was a major move. The typographer put together a user-friendly, compatible computer system to replace the stand-alone Linotype. The quality of camera-ready copy from the LaserMaster printer (1000 dots per inch) matches the copy produced from the photochemical-based processor. The upgrade also cut yearly commodity and service costs by several thousand dollars.

Production of camera-ready copy July 1991 to June 1992

Bulletin series

B 97. *Geology of the Goreville 7.5-Minute Quadrangle.*
1992. R. J. Jacobson, 32 pages, 20 figures, 3 appendices.

Circular series

C 548. *Upper Pennsylvanian Algal Bank Limestones on*

Table 2. Graphics*

	1989-90	1990-91	1991-92
Assorted maps, cross sections, graphs, layouts	556	591	464
Graphics for ISGS publications*	537	466	751
Large format items (60 to 150 hrs each)	-	12	16
Typographics (number of pages)			
Text, slides, tables, forms, charts	2,600	2,037	2,031
Photographics			
Photography for staff (about 25% of the black/white shots are printed; all negatives are filed)			
• field		5,880	
• lab		864	
• studio		1,536	
• total	4,800	5,200	8,280
2×2 inch slides (not only flat art, but also specimens)			
• originals	3,100	2,950	3,228
• duplicates	2,900	3,000	2,000
• total	6,000	5,950	5,228
Negatives for print plates (9×12 or 12×18 in.)	300	250	704
Internegatives	480	450	376
PMT prints developed for staff, total	5,430	5,800	6,678
• screened	210	320	924
• line (reverse and acetate)	5,220	5,480	5,754
Prints (total reflects 2-3 prints made of each selected exposure)			
• photographic		3,299	
• contact prints		312	
• contact sheets		308	
• total	5,250	4,950	4,119

* artists design, create layouts, and paste up publications—work that cannot be fully reflected in these numbers of illustrations.

Northern Margin of the Illinois Basin, Livingston County, Illinois. 1991. G. S. Fraser. 16 pages, 6 figures.

C 549. *Benefits and Costs of Geologic Mapping Programs in Illinois: Case Study of Boone and Winnebago Counties and Its Statewide Applicability*. 1991. S. B. Bhagwat and R. C. Berg. 40 pages, 5 tables, 2 figures, 3 appendixes.

Environmental Geology series

EG 140. *Illinois Geographic Information System: Applications to Environmental Management*. 1991. R. J. Krumm, A. L. Erdmann, and M. G. Joselyn (INHS). 32 pages, 1 table, 13 figures.

EG 141. *Construction, Monitoring, and Performance of Two Soil Liners*. 1991. I. G. Krapac, K. Cartwright, B. R. Hensel, B. L. Herzog, T. H. Larson, S. V. Panano, J. B. Risatti, W.-J. Su, and K. R. Rehfeldt (ISWS). 118 pages, 33 tables, 63 figures.

EG 142/HWRIC RR-058. *Optimal Time for Collecting Volatile Organic Chemical Samples from Slowly Recovering Wells*. 1991. S.-F.J. Chou, B. L. Herzog, J. R. Valkenburg, and R. A. Griffin. 18 pages, 7 tables, 6 figures, 2 appendixes.

EG 143. *Natural Recharge of Groundwater in Illinois*. 1992. B. Hensel. 38 pages, 1 table, 25 figures.

Cooperative Groundwater Report series

Coop 13. *Regional Groundwater Resources in Western McLean and Eastern Tazewell Counties with Emphasis on the Mahomet Bedrock Valley*. 1992. J. P. Kempton and A. P. Visocky (ISWS). 41 pages, 3 tables, 18 figures. 4 plates as ISGS Open File Series 1991-14.

Coop 14. *Pilot Study: Agricultural Chemicals in Rural, Private Wells in Illinois*. 1992. E. Mehnert, G. B. Dreher, W. S. Dey, S.-F.J. Chou, J. Valkenburg, and M. L. Barnhardt (ISGS); S. C. Schock, M. E. Caughey, S. Wilson, C. Ray, J. M. Gosar, and J. R. Karny (ISWS); W. F. Black, M. R. Brown, and V. J. Garcia (IDOA). 80 pages, 30 tables, 17 figures.

Coop 15. *Characterization of the Study Areas for the Pilot Study: Agricultural Chemicals in Rural, Private Wells in Illinois*. 1992. M. L. Barnhardt and E. Mehnert (ISGS); C. Ray and S. C. Schock (ISWS), editors. 114 pages, 11 tables, 56 figures.

Illinois Minerals series

IM 107. *Measuring Coal Seam Thicknesses with Normal*

- Lateral Electric Logs.* 1991. D. Berggren. 26 pages, 3 tables, 9 figures, 2 appendixes.
- IM 108. *Illinois Mineral Industry in 1989 and Review of Preliminary Mineral Production Data for 1990.* 1991. I. E. Samson. 43 pages, 25 tables, 13 figures.
- Illinois Petroleum series**
- IP 135. *Reservoir Heterogeneity and Improved Oil Recovery of the Aux Vases (Mississippian) Formation at King Field, Jefferson County, Illinois.* 1991. H. E. Leetaru. 49 pages, 33 figures, 4 photos, 2 appendixes.
- IP 137. *Potential for Improved Recovery within the Cypress Formation at Bartelso Field.* 1992. S. T. Whitaker and A. Finley. 44 pages, 34 figures, 8 photos, 8 appendixes.
- Illinois Basin Studies series**
- IBS. *Illinois Basin Consortium Program Plan.* 1992. D. R. Kolata, B. D. Keith (Indiana Geological Survey), and J. A. Drahovzal (Kentucky Geological Survey). 21 pages, 2 figures, 2 appendixes (tables).
- Special Report series**
- SR 1. *Geologic Mapping for the Future of Illinois.* 1992. ISGS staff. 49 pages, 5 tables, 43 figures, 2 annexes.
- Guidebook series**
- G 24. *Structure and Tectonics of the Rough Creek Graben, Western Kentucky and Southeastern Illinois* (original guidebook for GSA event). 1992. W. J. Nelson and D. K. Lumm. 34 pages, 12 figures, 1 photo.
- Open File Series**
- OFS 1991-7R. *Potential for Agricultural Chemical Contamination of Aquifers in Illinois Counties.* D. P. McKenna and D. A. Keefer. 18 pages.
- OFS 1991-7S. *Potential for Agricultural Chemical Contamination of Aquifers in Illinois Counties.* D. P. McKenna and D. A. Keefer. 1 state map (scale 1:500,000) and 102 county maps (full color, computer-generated maps).
- OFS 1991-7C. *Potential for Agricultural Chemical Contamination of Aquifers in Illinois Counties.* D. P. McKenna and D. A. Keefer. 102 county maps in black/white.
- OFS 1991-9. *Production of Superclean Coal by Wet-Grinding and Selective Flocculation.* C.-L. Chou, C. A. Woodward, and C. Chaven. 36 pages, 22 tables, 5 figures.
- OFS 1991-11. *Optimal Time for Collecting Volatile Organic Chemical Samples from Slowly Recovering Wells: Appendixes.* S.-F.J. Chou, B. L. Herzog, J. R. Valkenburg, and R. A. Griffin. 39 pages, 35 tables.
- OFS 1991-12. *Hydrogeology of Shallow Groundwater Resources, Aurora and Vicinity, Kane County, Illinois.* T. H. Larson, S. S. McFadden, and R. H. Gilkeson. 19 pages, 2 tables, 10 figures.
- OFS 1991-13. *Hydrogeology of Shallow Groundwater Resources in the Vicinity of St. Charles, Kane County, Illinois.* W. J. Morse and T. H. Larson. 12 pages, 2 tables, 8 figures.
- OFS 1991-14a. *Location and Summary of Well and Test Hole Data* (1:62,500-scale map from Coop 13, Re-
- gional Groundwater Resources in Western McLean and Eastern Tazewell Counties with Emphasis on the Mahomet Bedrock Valley). J. P. Kempton. Available for diazo reproduction.
- OFS 1991-14b. *An Interpretation of the Bedrock Topography of the Confluence Area of the Mahomet and Mackinaw Bedrock Valleys* (1:62,500-scale map from Coop 13). J. P. Kempton.
- OFS 1991-14c. *Distribution and Elevation of the Top of the Mahomet-Sankaty Sand* (1:62,500-scale map from Coop 13). J. P. Kempton.
- OFS 1991-14d. *Occurrence of Mahomet-Sankaty Sand and Probable Aquifer Characteristics* (1:62,500-scale map from Coop 13). J. P. Kempton.
- OFS 1991-15. *Results of a Shallow Seismic Refraction Survey near the Village of North Aurora, Illinois.* T. H. Larson and P. G. Orozco. 18 pages, 1 table, 6 figures.
- OFS 1992-1. *Characterization of Organic Sulfur in Mace-*
rals and Chars. R. D. Harvey and I. Demir. 21 pages, 5 tables, 8 figures, 6 photos.
- OFS 1992-2. *Southwest-Northeast Cross Section in the Illinois Basin: Sparta Shelf, Southern Illinois, to Rough Creek Graben, Western Kentucky.* J. D. Treworgy, S. T. Whitaker, M. L. Sargent, and M. C. Noger.
- OFS 1992-3. *Northwest-Southeast Cross Section in the Illinois Basin: Sparta Shelf, Southern Illinois, to Rough Creek Graben, Western Kentucky.* S. T. Whitaker, J. D. Treworgy, M. L. Sargent, and M. C. Noger.
- OFS 1992-4. *Wet-East Cross Section in the Illinois Basin: Ozark Dome, Missouri, to Rough Creek Graben, Western Kentucky.* M. L. Sargent, J. D. Treworgy, and S. T. Whitaker.
- OFS 1992-5. *Hydrogeology of Shallow Groundwater Resources, Geneva-Batavia Township, Kane County, Illinois.* T. H. Larson, S. S. McFadden, and R. H. Gilkeson. 15 pages, 2 tables, 10 figures.
- OFS 1992-6. *Hydrogeologic Environments along the Fox River Valley in Kane County, Illinois.* F. A. Fitzpatrick, T. H. Larson, S. S. McFadden, and R. H. Gilkeson. 24 pages, 2 tables, 11 figures.
- OFS 1992-7. *Quaternary Geology of the Creal Springs 7.5-Minute Quadrangle, Illinois* (map). M. H. Riggs, M. S. Lannon, S. P. Esling (SIU), and L. R. Follmer.
- OFS 1992-8. *Quaternary Geology of the Eddyville 7.5-Minute Quadrangle, Illinois* (map). E. D. Henderson, M. S. Lannon, and S. P. Esling (SIU); M. H. Riggs and L. R. Follmer.
- OFS 1992-9. *Quaternary Geology of the Stonefort 7.5-Minute Quadrangle, Illinois* (map). M. S. Lannon and S. P. Esling (SIU); M. H. Riggs and L. R. Follmer.
- OFS 1992-10. *6 O'Clock Cross Section in the Illinois Basin: Wayne County, Illinois, to Gibson County, Tennessee.* S. T. Whitaker, J. D. Treworgy, and M. C. Noger.
- Illinois Geologic Quadrangles (IGQ) and Other ISGS Maps, Cross Sections, Stratigraphic Columns**
- IGQ 7. *Geologic Map of the Goreville Quadrangle, Johnson and Williamson Counties, Illinois.* 1991. R. J. Jacobson with contributions by H. H. Damberger and C. B. Trask. Full color, scale 1:24,000.
- IGQ 8. *Geologic Map of the Waltersburg Quadrangle, Pope*

County, Illinois. 1991. C. P. Weibel, W. J. Nelson, and J. A. Devera. Full color, scale 1:24,000.

IGQ 9. *Geologic Map of the Glendale Quadrangle, Johnson and Pope Counties, Illinois*. 1991. J. A. Devera. Full color, scale 1:24,000.

Reprints of papers published in journals, proceedings, or other compilations

1991K, *Water Movement Through an Experimental Soil Liner*, I. G. Krapac, K. Cartwright, S. V. Panno, B. R. Hensel, K. R. Rehfeldt, and B. L. Herzog • 1991L, *Mahomet Bedrock Valley in East-Central Illinois: Topography, Glacial Drift Stratigraphy, and Hydrogeology*, J. P. Kempton, W. H. Johnson, P. C. Heigold, and K. Cartwright • 1991M, *Variation of Organic Sulfur in Macerals of Selected Illinois Basin Coals*, I. Demir and R. D. Harvey • 1991N, *Distribution and Forms of Chlorine in Illinois Basin Coals*, C.-L. Chou • 1991O, *Effects of Wetlands Creation on Groundwater Flow*, B. R. Hensel and M. V. Miller • 1991P, *Benefits of Using Calcium Oxide Additive in the Mild Gasification of Coal*, C. W. Kruse, A. D. Williams, and C. Feizoulof • 1991Q, *The Youngest Carpoid: Occurrence, Affinities, and Life Mode of a Pennsylvanian (Morrowan) Mitrate from Oklahoma*, D. R. Kolata, T. J. Frest, and R. H. Mapes • 1991R, *Importance of Geologic Characterization of Potential Low-Level Radioactive Waste Disposal Sites*, C. P. Weibel and R. C. Berg • 1991S, *Coalification in North American Coal Fields*, H. H. Damberger.

1992A, *Environmental Benefits Versus Costs of Geologic Mapping*, S. B. Bhagwat and R. C. Berg • 1992B, *Is Coal Price Linked to Oil Prices? Analysis of U.S. Fossil Fuel Prices in 1971-1988*, S. B. Bhagwat • 1992C, *Paleopedology and Conodont Biostratigraphy of the Mississippian-Pennsylvanian Boundary Interval, Type Grove Church Shale Area, Southern Illinois*, C. Pius Weibel and R. D. Norby • 1992D, *An Analytical Study of a Two-Layer Transient Thermal Conduction Problem as Applied to Soil Temperature Surveys*, T. Larson and A. T. Hsui • 1992E, *Thrust Faults in the Southern Illinois Basin—Results of Contemporary Stress?* W. J. Nelson and R. A. Bauer.

Educational Extension Geological Field Trip booklets

1991-C. *Decatur Area, Macon County*. D. L. Reinertsen. 41 pages, 25 figures.

1991-D. *Pere Marquette State Park, Jersey County*. D. L. Reinertsen and J. Treworgy. 34 pages, 18 figures.

1992-A. *Cave in Rock and Rosiclare Area, Hardin County*. D. L. Reinertsen. 39 pages, 15 figures.

1992-B. *Galena Area, Jo Daviess County, Illinois, and Lafayette County, Wisconsin*. D. L. Reinertsen. 37 pages, 20 figures.

Special publications

Posters, major slide programs for Rostam-Abadi (2), Muckensturm (2), Howard, DuMontelle, Su, Cole (2-3 stages), Kolata, Curry, Grube/Leetaru, Herzog (2), Nelson, Follmer, Hensel, McKenna, Robinson (INHS), J. Treworgy, Whitaker, Dexter, and parts of presentations for Kolata/Norby, Brower, and

Hughes. Posters and slides are full-scale productions that require editing, typography, photography, and graphics.

Papers, misc text (>5 pages) for Bhagwat, McKenna, Nelson and Langenheim, C. Treworgy, Devera, Killey, Risatti, Dreher, Krumm, Roy (2), Goodwin, Hughes, Masters/Berg, Peppers. Also, abstracts for Nelson, VanRoosendaal, Stohr (2), and Curry.

Catalog. 1991 Additions to the Geological Samples Library. 1992. C. J. Zelinsky.

Geonews. December 1991

Two annual reports • Illinois State Geological Survey, July 1990 - June 1991. 164 pages, 47 photos • Illinois State Geological Survey Addresses Challenges for a Healthy Economy and a Healthy Environment. 25 pages, 25 photos.

TECHNICAL DESIGN, OPERATION, AND MAINTENANCE

Kaczanowski This program offers multiple services to the ISGS. A woodworking shop, metal and machine shop, electronics shop and automotive section, and a drill rig and operator provide special services to scientific staff. Versatile craftsmen design, construct, maintain, and repair equipment and instruments. Staff also provide custom drilling services as well as schedule and maintain the ISGS automotive and special vehicle fleet. They are responsible for the repair and maintenance of the Shop and Equipment Building, the clay liner facility, and ISGS laboratories at the Natural Resources Building, Annex, and Applied Research Lab.

During the report period, the unit completed 338 internal work orders and 268 verbal requests for repair, fabrication, moving, maintenance, or other services.

Highlights of Activities The second phase of the Natural Resources Building laboratory upgrade was completed this year. Shop staff were responsible for moving laboratory and office equipment, reestablishing scientists in their laboratories, and overseeing completion of all work.

Design and equipment construction took many forms, notably the design and building of equipment for the High-Surface-Area Hydrated Lime Project.

The ISGS received 178 pieces of assorted office equipment from the Illinois Mine Subsidence Insurance Fund. The staff cleaned and repaired the furniture, then moved it from the garage to appropriate locations.

Because of budget and staff restrictions, shop staff also assisted with preparing and cataloguing oil well samples at the Geological Samples Library and helped with various tasks at the ISGS Duplicating Shop.

Woodworking Shop

Custom computer workstations, tables, desk organizers, book shelves, and map cases are a specialty of the woodworking and metal shops. In this report period, 52 different types were constructed, including two special outdoor, weathering experiment cabinets. Staff also painted file cabinets and repaired coat racks, chairs, and other wood furniture.

Machine and Metal Working Shop

The machine shop routinely designs and constructs special apparatus for the ISGS staff. On the list of this year's products are improved well points and connecting rods with special threads to reduce down time in the field in soil gas sampling. For the Hydrogeology Section, staff made a Parshall Flume of welded aluminum construction. For the Groundwater Protection Section, staff machined a special mold from aluminum stock, then constructed a stainless steel superstructure.

Electronics Shop

The electronics shop provides support in electrical/electronic maintenance, repair of scientific equipment, and coordination of site preparation for installation of new equipment at the ISGS. Network and other computer cabling hook-ups, as well as telephone installation and repair, are other shop responsibilities.

Staff assisted in site preparation of the Process Optimization Unit for the hydrated lime process at the Applied Research Lab. They also performed the electrical wiring for hook-up of several pieces of specialized equipment.

Repair of field equipment is handled rapidly and efficiently by shop staff. During FY92, they repaired downhole logging equipment for the Hydrogeology Section and maintained a number of portable instruments for field use.

Drill Rig

The ISGS drill rig and operator were utilized in six projects during this report period. Projects included monitor well installations, split spoon sampling, continuous sampling, and mine subsidence studies. The drill rig operator coordinated work with ISGS staff to effectively complete research projects. He also performed routine drill rig maintenance, in addition to his other assignments.

Automotive Section

Servicing and keeping records of the 25 ISGS vehicles and 55 vehicles of the Illinois Natural History Survey are responsibilities of the automotive staff. The section also handles dispatching and new vehicle requisitioning for the ISGS vehicles.

This year, 246 lube-and-oil changes were completed; and 207 car washes took place in the ISGS wash stall. In addition to routine fueling, window and interior cleaning, and tire changing, staff installed trailer hitches and mud guards, and completely overhauled an inflatable boat trailer. Vehicles were also taken to the State garage for major repairs.

Staff requisitioned three new replacement vehicles for the fleet. The ISGS operational cost for the fleet this year was a low 10.9 cents per mile, even though the cost of gas increased during a major portion of the year. Following a strict maintenance schedule has kept costs to a minimum.

Applied Research Laboratory Shop Services

Cooper The ARL shop custom designs, fabricates, and repairs laboratory and scientific apparatus for projects

of the Applied Research Lab. Without the ARL shop, these services would have to be handled outside and at additional cost. Principal accomplishments during this report period included the following:

- designing and building equipment for the continuous flow, process optimization unit (POU) of the High-Surface-Area Hydrated Lime Project (see project description, p. 7); also modifying the unit, housing, and instrumentation, and ensuring its safe operation;
- assisting in operation of the POU;
- assisting in design and construction of equipment for the Carbonation of Pellets Project;
- installing a 20-foot, 4-inch glass column and related equipment for the Static Tube Column Project.

At least 80% of the time went towards the work on the High-Surface-Area Hydrated Lime Project.

EDUCATIONAL EXTENSION

Reinertsen Information and materials on the geology, mineral resources, and landscape of Illinois are provided to elementary, high school, and college teachers, students, and the general public. The Educational Extension staff also presents slide-illustrated talks about ISGS research and service to teacher workshops and citizen groups throughout the state.

Geological Science Field Trips

Although designed to furnish teachers with background materials for classroom use, the four field trips held each year are also popular events for the public. A guidebook is furnished to the participants. Other guidebooks from about 80 previous field trips are kept on file in the Educational Extension office; copies are available for teachers and others.

The ISGS hosted field trips to the Decatur area in September 1991, the Pere Marquette State Park area in October 1991, the Cave In Rock and Rosiclare area in April 1992, and the Galena area in May 1992. Of the 697 attendees, 154 were elementary, high school, and college students; and 81 were elementary, secondary, and college teachers.

Teacher Workshops

Educational Extension staff presented three teacher workshops on rock and mineral identification in the classroom: two were held at Oakton Community College for the North Cook County Regional Superintendents Office in November 1991; and another was conducted for teachers in the Evanston school district in February 1992. The movie, "Geology Is...", was shown and a slide talk about the geology of the Chicago area presented to student teachers and teachers at the National Education College in Evanston in November 1991. A special geological science field trip was conducted in the Canton area for a teacher workshop in June 1992.

Other Activities

Color slides from the unit's extensive collection were used by several staff members from other ISGS sections

for publications and talks. The head of this unit attends meetings of the Statewide Advisory Board on Conservation Education of the Illinois State Board of Education; he is also one of the ISGS representatives on the Groundwater Protection Education Subcommittee.

EarthNet: Building a Community of Geoscience Educators, Jacobson, Berggren, Vaiden (ISGS); Waugh, Levin (UI-UC, College of Education); Langenheim (UI-UC, Museum of Natural History); Nelson (Illinois State University, Department of Geography and Geology) A proposal to fund a field course in geology for teachers was submitted to the Illinois State Board of Education for Funding. In August 1991, the ISGS was informed that the Board of Education chose not to fund the proposal.

GEOLOGICAL RECORDS UNIT AND SAMPLES LIBRARY

Zelinsky As a result of the continued downturn in the oil and gas industry, the volume of data handled by the Geological Records Unit (GRU) decreased slightly in 1991-92 (table 3). The reduction of records received from the petroleum industry was partially offset by the revitalized efforts of the ISGS and the Illinois Department of Mines and Minerals (IDMM) to obtain old well records required for submission to the State. Although the number of visitors and volume of data handled by the Geological Records Unit decreased during the past year, the number of visitors and volume of oil well samples processed by the Geological Samples Library increased significantly in 1991-92.

Geological Records Unit

GRU is the repository for drilling records in Illinois, as mandated by statute (Illinois Oil and Gas Act—Illinois Revised Statute, Chapter 96 1/2, Paragraph 5409, Section 4). The collection includes oil and gas wells, water wells, engineering borings, and miscellaneous test holes. This database has long been of value to the oil industry, coal industry, hydrogeologists, engineers, land use planners, academic institutions, landowners, general public, and ISGS staff.

Total pieces of mail processed decreased slightly (476 fewer than in FY92). New oil well permits received increased (1,462 more than FY92) as a result of the IDMM effort to permit those producing wells drilled prior to 1940—wells that did not have permits issued for them at the time. Water well permits received also increased (1,961 more than FY92).

GRU staff continued to assist visitors and ISGS scientists with requests for information regarding drill-hole records on file. Use of the facility decreased by 50 visitor days (979) during the report period. Of the 979 visitors to GRU, 413 were independent operators; 566 visitors represented companies, governmental organizations, or universities. Staff received 3,558 phone requests, 33 less than the previous year. Total orders processed increased by 310 (2,147 in FY92, as compared with 1,837 the previous year). Staff also copied 6,475 continuous logs and 38,706 single sheets of well data (as compared with 7,216 continuous logs and 49,107 single sheets during the previous year).

New Rules of the Illinois Department of Mines and Minerals Effective September 30, 1991, new IDMM requirements for submitting well information and well cuttings went into effect. A newly created Well Drilling Report (OG 5) is required for all wells drilled or deepened. The form contains many features of the scout ticket and driller's log. According to the new IDMM rules, the following must be submitted to the ISGS within 90 days after completion of drilling:

1. Well Drilling Report (OG 5) (not required for conversions that do not entail deepening of the well);
2. copy of all wireline or geophysical logs run in the well;
3. drilling time log, or geograph record, if no wireline logs were run (not required for wells drilled with air rotary or cable tools);
4. well cuttings and drilling time, as required on the permit.

Effective October 10, 1991, the period a well may be held confidential increased from 1 to 2 calendar years from permit issue date. The Well Drilling Report (OG 5) is a compliance item to be tracked by ISGS at the request of IDMM. Failure to submit this form places operators on the quarterly list of non-compliant operators, as requested by IDMM. Changes were made to the ISGS computer program to comply with these changes in rules.

Database Transfer The CONQUEST system, used on the VAX workstation, went online in January 1992. Version 4 of the program containing a number of requested modifications has been installed and is being used daily. All GRU files have been transferred from the PRIME mainframe computer system. GRU discontinued the practice of entering data into PRIME computer data files and disconnected from the PRIME mainframe computer July 1. Staff working with the Well Database Unit continued to add and update records in the database.

Water Well Records Task Force Since November 1988, GRU has used a task force approach to process the backlog of water records in three phases. With the cumulative entry of 16,503 records during January 1992, phase three was completed. During the past three years, the task force has (1) applied the CONQUEST software program for data entry and printing of water summary sheets, (2) entered 58,106 permits and/or logs into the system in three phases; (3) consolidated the paper files into a retrievable file system; (4) improved data exchange with the Illinois State Water Survey; (5) assisted the Illinois Department of Public Health and some counties to implement new rules for submitting data to state agencies; and (6) added 155 log books with new water well data to the ISGS collections.

The task force approach has been effective. By processing 16,503 records, the Water Well Records Task Force met its goals. Effective February 1, 1992, the task force catch-up was complete, and the Geological Records Unit is now in maintenance mode for both water and oil records.



A



B



C



D

(A) William H. Revell and John Klitzing of the Samples Library sort incoming well cuttings. (B) LeAnn Benner, information specialist, fills a customer order for topographic maps. (C) Renaé Strawbridge and Nancy Martinkus of Business and Financial Services review inventory records of ISGS equipment. (D) Tonia J. Vaughn of Geological Records searches for well information to fill a customer request.

Groundwater Database Activities, E. Smith, GRU staff
 ISGS staff continue to develop and update an automated groundwater database, utilizing water well records and other subsurface information on file at the ISGS. The main purpose of the project is to develop a database of subsurface information that will be accessible to ISGS staff, outside researchers, and the general public via the computer network and individual workstations. The format of the database was originally developed by staff of the Groundwater Protection and Hydrogeology Sections in conjunction with the Geologic Records Unit and the Well Database Unit. Technical assistance and advice is provided to GRU staff to reconcile discrepancies found within the water well records and permits. Assistance in acquiring water well records and permit information from county health departments throughout the state is also given to GRU.

Data Acquisition Oil well permits issued (3,072) by IDMM increased by 1,462 from last year's 1,610. Oil and water well plugging affidavits received increased during the report period; of the 3,459 affidavits received, 1,315 were for oil wells (as compared with 1,079 for oil the previous year) and 2,144 for water wells (as compared with 1,936 the previous year). The total of new logs received was 10,262, down from the 12,528 received the previous year (table 3).

Geological Samples Library

Staff of the ISGS Geological Samples Library (GSL) manage one of the largest physical collections of geological samples in the United States. They receive, process for storage, and archive these important collections as mandated by statute (Illinois Oil and Gas Act—Illinois Revised Statute, Chapter 96 1/2, Paragraph 5409, Section 4). The ISGS began collecting samples in the early 1900s when the U.S. Geological Survey provided a series of drill cuttings to the state geologist. Today, this unique repository houses cores and cuttings that represent billions of dollars invested in Illinois by petroleum, mining, and engineering companies. The collection attracts users across the country and thus increases the potential for in-state and out-of-state investment in Illinois. It also provides the essential database for investigating environmental and resource issues.

Visitors and staff referred to GSL files 265 times (41 more than in FY92) and studied 848 sets of samples or core (216 more than in FY92). Visitors to the Annex facility represent a wide range of geologic interests. Independent consultants and representatives of major oil companies, universities, and government agencies are typical visitors to GSL. Of the 148 visitors (65 more than in FY92) to GSL, 41% were from out-of-state.

Samples Library personnel assemble rock and mineral kits for distribution to Illinois schools. A 35-specimen set is designed to familiarize teachers and students with the rocks, minerals, and fossils of Illinois. In the past year, 109 specimen kits (20 fewer than in the previous year) and 19 orders were filled for the reconditioning of sets.

Table 3. Annual GRU Statistics

Data Acquisition	1990-91	1991-92
<i>Basic data</i>		
Oil permits	1,610	3,072
Water permits	6,488	8,449
Water Task Force records	19,733	10,388
Plugging affidavits - oil	1,079	1,315
- water	1,936	2,144
<i>Logs</i>		
Electric logs	1,517	515
Micro logs	290	179
Radioactivity logs	1,517	787
Miscellaneous geophysical logs	227	66
Total geophysical logs	3,551	1,547
Drillers logs	379	93
Drilling time logs	942	213
Company sample and core studies	194	24
Geologic tops	119	94
General data (completion data)	1,500	1,348
Water well and test hole logs	4,422	5,966
Miscellaneous	1,421	977
Total new logs received	12,528	10,262
<i>Cumulative Totals</i>	<i>Through FY92</i>	<i>June 1992</i>
<i>Collections</i>		
Processed drill hole records	10,896	342,026
Books of processed drill-hole records	16	1,013
Skeleton logs (records prior to 1920)		17,920
Books of skeleton logs		40
Books of confidential logs		15
Books of out-of-state logs		14
Books of miscellaneous drill-hole records		9
Geophysical logs	1,547	132,320
Coal plugging	673	22,674
<i>Service Activities</i>	<i>1990-91</i>	<i>1991-92</i>
Total mail processed	23,641	23,168
Visitor days	1,029	970
Files used by public and staff	54,263	45,637
Phone calls	3,581	3,558
Copies - continuous logs	7,216	6,475
- single sheets	49,107	38,706
Total orders processed	1,837	2,147
Copies to state agencies/staff		
- single sheets	10,099	9,177
- logs	204	219

Acquisition of Sample Cuttings Oil and water well cuttings added to the GSL during the report period increased the total footage of cuttings to 742,997,131 feet. During FY92, 388 sets of well cuttings were added to the permanent file (141 more sets than in the previous year). The additions represented more than 743,012 feet of drilling. These samples are contained in 814 boxes. About 231 sets of well cuttings were requested from permits issued last year, as compared with 291 the previous year. The GSL files of 67,512 sets of well

cuttings are stored in 103,730 boxes and utilize 1,445 linear feet in a 3,780-square-foot area of the facility.

Samples from an additional 147 oil and water wells (24 fewer than in the previous year) await processing. At present, the interval between receipt and permanent processing is 6 months, a 3-month decrease in processing time over last year.

Additions to our permanent files consisted of 304 oil test sets (197 more than in the previous year) from rotary drill wells washed, and 84 water wells (56 fewer than in the previous year).

Cores Rock cores from oil and mineral borings that were added to GSL during the report period increased the total footage of core to 1 million feet. During the report period, seven cores (128 fewer than the previous year) representing an initial 9,778 feet of drilling were collected, examined, and processed into the permanent files. This year's additions are housed in 99 cardboard core boxes assembled by GSL staff. The entire collection of 13,625 sets of core on permanent file is stored on steel racks in an area covering approximately 4,300 square feet of the facility. GSL has received a number of significant core collections that are to be processed into current collections. Currently, new acquisitions received will exhaust most of the remaining storage space for core in the Natural Resources Studies Annex. Space for cores at the ISGS has become a priority issue.

Cores and Cuttings Samples Presented to the ISGS by Panhandle Eastern Pipeline Company, Houston, Texas, Sargent, Lasemi Nineteen cores, 3.5 to 4 inches in diameter, totaling approximately 2,600 feet of rock from the Ordovician and Cambrian Systems in Champaign, Douglas, and Morgan Counties were donated to the ISGS. The cores will be used to determine the porosity and permeability of the potential reservoir and cap-rock strata at the Tuscola and Waverly Gas-Storage Fields and other potential storage sites. In addition to the cores, more than 150 cuttings sample sets were received from structure tests in Mason, Tazwell, and Douglas Counties and from injection-withdrawal wells at the storage fields. Three of the 19 cores were described, stratigraphically identified, and placed in the research collection.

Extra cuttings samples and cores that duplicate material already in GSL will be offered to educational institutions throughout the state, interested scientists for destructive testing, or the U.S. Geological Survey for its studies of the evolution of sedimentary basins.

Other Sample Collections

ISGS staff generate a large volume of research materials. GSL staff receive, sort, and file these materials in the Staff Research Collections storage area of GSL. About 37,265 items, mostly analytical samples, are on file at the Annex.

ISGS provides sample bags for collection of well sample cuttings requested on permits issued by the state. In this report year, GSL supplied drillers and operators with 18,450 sample bags (650 more than last year).

The GSL office houses the ISGS microfiche collection of well log information. Staff sell copies or assist visitors who wish to examine the collection. During the past report period, 6,457 microfiche were added to the collection; the total is now 88,920 microfiche.

CAPITAL PROJECTS FACILITIES UPGRADE

Glogowski The \$630,000 Lab Upgrade Project was completed. The upgrade included the following laboratories.

Natural Resources Building

Room	Lab Name
5	Engineering Geology
20	Isotope Geochemistry
22	Core Laboratory
26	Rock Grinding
31	Industrial Minerals
33	Industrial Minerals
207	Mining Geology
217	Coal Petrography
223	Low Temperature Ashing
301	Petrography
302	Isotope Geochemistry
311	Oil and Gas
325	X-Ray Fluorescence
331	Furnace Room
335	Microbial Geochemistry
364	Mass Spectrometer
403	Photo Lab
425.A	Groundwater Lab
425.B	Groundwater Lab
435	Groundwater Lab

Work consisted of the following:

- replacing chemical fume hoods and relocating motors and fans to the roof or attic, so that fume vents have negative internal pressure through most of their run from workspace to exit vent;
- relocating or installing shower drench stations;
- installing eye and face wash stations;
- replacing laboratory benches and sinks that had corroded plumbing, unsafe and inadequate electrical service, corroded and porous work surfaces, inadequate or unsafe utility service; replacing and improving utilities;
- installing wall cabinets to provide enclosed storage of reagents and glassware, especially where inadequate shelving and other storage space for essential laboratory equipment had resulted in work space being used for storage;
- replacing old incandescent lights with fluorescent lights to help keep laboratories cool, avoid the possibility of igniting explosive gases in the event of lamp globe breakage, and increase the illumination in the laboratories;
- repainting the laboratories with light colors to further increase the apparent brightness of room illumination;

- extending the make-up air system;
- removing asbestos.

In conjunction with the Illinois Natural History Survey, the ISGS is in the planning and development stage of a \$3.44 million upgrade to the Natural Resources Building. The upgrade is intended to include the following:

- provide air conditioning for ISGS laboratory make-up air units;
- upgrade electrical service throughout the building; replace incandescent lamps with fluorescent lights;
- replace three elevators; replace steel entrance doors and frames;
- provide patching and interior wall painting to all walls not treated in recent upgrades;

- provide acoustical ceilings and extend the fire alarm system as required;

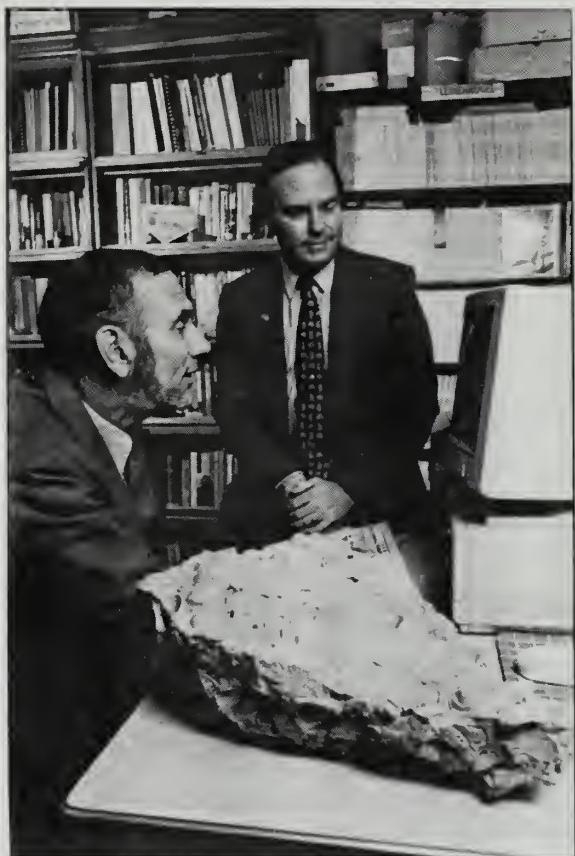
- provide new venetian blinds;
- provide new vinyl floor or carpet;
- replace 120 window air conditioners that are more than 10 years old;
- provide permanent dividing walls and doors for 25 rooms;
- replace the deionized water unit in room 436 west as well as supply lines and valves throughout the building.

For FY93, \$200,000 has been appropriated to plan and develop the upgrade of the Applied Research Lab. The remainder of the approximately \$1 million will be requested to continue the project in FY94.



A

B



C



ACTIVITY MEASURES

All Illinois State Agencies are required to provide activity measures as part of their annual budget presentations to the General Assembly. Selected activity measures also are included in the Governor's report on the State budget. Internally, we use a wide range of activity measures to gauge how effective we are at reaching the public with our information and services. The measures also are helpful indicators of where our research and service staff are applying their greatest energies, and to what degree we may need to adjust or reshape our program, budget, or organization. The table at the end of this section shows selected activity measures, distributed by program areas.

Some annual activity measures are calculated from samples taken for a few months; for example, the total number of long-distance phone calls made by staff is calculated from the total number of calls billed to all ISGS telephones during August of 1991, and January and February of 1992. The numbers of telephone calls and visitors recorded for the Information Office are also based on a sample count for a short period. We believe that these estimates are sufficient to gauge trends from one year to the next.

Measures

Research Activities ISGS scientists reported 127 state-funded research projects in progress during the year, three fewer than last year. Of these, 70 were in the Mineral Resources Program, 22 in the Environmental Geology Program, and 35 in General and Basic Research. Our scientists reported that 97 sponsored research projects were active during the year, of which 56 were in the Mineral Resources Program, 33 in the Environmental Geology Program, and eight in General and Basic Research. According to the count maintained by our grants and contracts administrative office, ISGS scientists submitted 99 proposals for sponsored research projects this year, six more than last year. Many of these proposals were submitted at the request of the sponsoring agency after preliminary negotiations. Consequently, at least 80% of the proposals submitted by the ISGS were accepted and at least partly funded.

To present our research information to the public and the scientific community, we published 396 articles, reports, maps, abstracts, and other formally released documents in the ISGS series and other outlets such as scientific journals, proceedings volumes, and guidebooks. The total is about 29% higher than that of last year. Publications included 24 computerized oil and gas development maps, 73 new editions of the coal mine directories and accompanying maps, reprintings of the state geologic map and Educational Series 4 and 5, and a limited number of duplicate citations that appear both in scientific journals and the ISGS Reprints series.

The Library and Map Room and the Information Office sold 7,209 copies of publications and 1,846 copies of maps. We distributed 13,068 free copies of ISGS publications, about 2,700 fewer than last year, and gave away 530 copies of ISGS maps, less than one-

half as many as in fiscal year 1991, but about the same number as in fiscal year 1990. The total of 22,653 copies of our publications distributed this year is about 18% less than last year. We also sold 19,941 U.S. Geological Survey topographic maps and distributed 2,430 free copies of these products. The number sold this year is about 2% more than last year.

Public, Government, and Industry Services

Information Responses To provide scientific information, we met with 5,737 visitors, about 5% less than the total for last year (see table). This decrease is primarily attributable to an 8% decrease in the number of visitors reported by the Information Office and a 13% drop in the number of visitors to the Geological Records Unit.

To respond to inquiries and conduct ISGS business, we sent out 1,486 letters (about the same as last year), but made 32,620 long distance phone calls (8% more than last year). Included in the outgoing calls were 3,348 facsimile transmissions, an increase of 6% as compared to the 3,172 faxes sent last year. The continuing increase in outgoing long distance phone calls (up 60% in 3 years) and facsimile transmissions perhaps reflects an increasing sense of urgency in the people's need for geologic information. The Information Office received an estimated 9,307 telephone calls, about 17% less than last year.

Demand for copies of well logs decreased, despite the relatively stable prices being offered for oil. The Geological Records Unit received 897 visitors this year, 13% less than last year, and sold more than 5,462 continuous copies of well logs. This represents a decrease of almost 24%, as compared to last year. The Geological Samples Library received 114 external visitors this year, as compared to 113 last year. Visitors used 278 sample sets.

Identifications, Analyses, and Reports of Results To conduct their various research and service projects during the year, ISGS chemists completed at least 27,778 separate elemental determinations on 2,047 samples of rock, soil, brine, and water. Other analyses included 2,649 elemental determinations by energy dispersive X-Ray analysis with the scanning electron microscope and 3,238 isotopic determinations on 2,438 samples. The coal analysis laboratory performed 4,000 proximate and ultimate analyses on 940 samples of coal. ISGS scientists also completed 1,880 mineralogical determinations by X-Ray diffraction, examined 230 thin sections of rocks, performed 65 low temperature ash determinations, identified 292 hand specimens for visitors, examined 224 drill cores and 383 sample sets, and measured 54 stratigraphic sections. The palynology lab completed determinations of the biostratigraphic age of 33 samples. Geotechnical analyses included 145 instrumental particle size determinations on suspended sediments, 284 sieve analyses, and 290 rock strength tests. The reservoir engineering laboratory conducted 150 porosity and permeability tests, 12 core flow tests, and 53 PVT tests of various kinds, and collected 2,500

Illinois State Geological Survey Selected Activity Measures 1990-1991

	Mineral Resources	Environmental Geology	General and Basic Research	Administrative Services	Total
Reports and maps					
Published	226	87	70	13	396
Distributed	--	--	--	--	22,653
Unpublished reports	93	338	15	21	467
Visitors and office					
conferences	955	211	214	4,357	5,737
Letter responses	424	143	741	844	1,485
Talks, posters, displays, interviews	189	174	52	42	457
Workshops, classes, seminars	60	58	22	14	154

minipermeameter readings. To explore for groundwater and for other purposes, our scientists ran 31 borehole logs, performed 51 electrical earth resistivity surveys, and ran a total of 10 line-miles of seismic profiles. To report the results of these analyses and for other purposes, our scientists prepared 467 unpublished reports, including five groundwater possibility reports, ten waste disposal site reviews, 97 environmental property assessment reports, three wetlands assessment reports, and 40 mine subsidence reports.

The staff of the Geologic Mapping and Digital Cartography Section and other scientists throughout the ISGS performed 110 data-entry tasks, digitized 305 maps, wrote 546 computer programs of various kinds, and plotted out 1,919 digital map files for internal use and external distribution.

Continuing Scientific and Educational Contributions
 ISGS staff members presented papers at scientific meetings, made speeches or other informational presentations at public meetings, discussed posters, participated in field conferences to consider geological problems with their colleagues, and otherwise transferred information to fellow scientists and the public on 457 occasions during the year, including 42 interviews with print, radio, and television reporters. In addition, our scientists either taught or participated in workshops, seminars, and classes on 154 occasions,

including a small number of presentations for elementary, secondary, and college classes. We advised graduate students in geology and other fields from across the state and nation, and throughout the world on at least 340 occasions during the year. The Educational Extension Unit hosted 697 persons on the four public field trips offered this year and distributed 109 complete rock and mineral sets, 19 partial sets, and 28 coal ball slices to Illinois schools.

Public, Industry, Government Contributions ISGS staff members serve on 56 advisory boards for local, state, or national government agencies or citizen groups. Our scientists presented oral or written testimony, or made other kinds of informational presentations to various advisory bodies on 80 occasions during the year. In addition, 104 of our staff members hold elective or appointive offices in various professional societies. Through those positions, they provide services to the scientific community, industry, and government by reviewing manuscripts for journals and proposals for funding agencies, organizing and chairing technical sessions at scientific meetings, hosting scientific meetings that bring visitors to the state, devising new standards for analytical methods, and publishing newsletters and summary articles that provide information about scientific, social, and industry trends.

FINANCIAL REPORT

Fiscal Year 1992

Appropriated Funds Of the available appropriated FY92 funds totaling \$5,912,500 (tables F1 and F2), the Illinois State Geological Survey expended all but \$700 (.01%) of General Revenue monies and \$81,100 (35.9%) in the Natural Resources Information Fund. Expenditures in the Natural Resources Information Fund were intentionally light as revenues did not fully support the appropriation.

Allocated Funds Of the available allocated FY92 funds totaling \$338,100 (tables F3, F4 and F5), the Illinois State Geological Survey expended all monies in the Building Repair and Maintenance line. Lapses occurred in LUMP \$1,000 (1.4%), Groundwater Protection Act - Hazardous Waste Research Fund \$100 (0.1%), Build Illinois Repair and Maintenance \$300 (0.4%), and Build Illinois Equipment \$100 (1.9%).

Table F1 FY92 Financial Statement for the Illinois State Geological Survey General Revenue Fund: July 1, 1991, through September 30, 1992 (\$ in thousands)

Line item	Original appropriation for FY92	Emergency budget act	Available appropriation for FY92	Transfers	Vouchered to date	Outstanding obligations this date	Balance available for FY92
Personal Services	\$5,134.8	(\$151.1)	\$4,983.7	0.0	\$4,983.7	\$0.0	\$0.0
Retirement Contributions	255.6	(19.9)	235.7	0.0	235.7	0.0	0.0
Social Security Contributions	10.8	(0.8)	10.0	0.3	10.3	0.0	0.0
Contractual Services	100.1	(3.0)	97.1	(6.8)	90.3	0.0	0.0
TopoMapping	19.3	(0.6)	18.7	0.0	18.7	0.0	0.0
Travel	39.6	(1.2)	38.4	(1.2)	37.2	0.0	0.0
Commodities	75.2	(2.3)	72.9	(13.5)	59.4	0.0	0.0
Printing	36.5	(1.1)	35.4	(1.8)	33.6	0.0	0.0
Equipment	38.5	(1.2)	37.3	(0.1)	37.2	0.0	0.0
Computer-Based Research	48.1	(1.4)	46.7	12.2	58.9	0.0	0.0
Telecommunications	54.0	(1.6)	52.4	10.4	62.8	0.0	0.0
Operation of Automotive Equipment	35.1	(1.1)	34.0	0.5	34.4	0.0	0.1
GeoMapping - Other Expenses	25.0	(0.8)	24.2	0.0	23.6	0.0	0.6
TOTALS	\$5,872.6	<u>(\$186.1)</u>	<u>\$5,686.5</u>	<u>\$0.0</u>	<u>\$5,685.8</u>	<u>\$0.0</u>	<u>\$0.7</u>

Table F2 FY92 Financial Statement for the Illinois State Geological Survey Natural Resources Information Fund (NRIF): July 1, 1991, through September 30, 1992 (\$ in thousands)*

Line item	Available appropriation for FY92	Transfers	Vouchered to date	Outstanding obligations this date	Balance
Lump Sum - Operating Expenses	\$225.0	\$0.0	\$144.9	\$0.0	\$80.1
Refunds	1.0	0.0	0.0	0.0	1.0
TOTALS	<u>\$226.0</u>	<u>\$0.0</u>	<u>\$144.9</u>	<u>\$0.0</u>	<u>\$81.1</u>

* NRIF receipts are insufficient to expend the full appropriation amount.

NRIF receipts July 1, 1991, through June 30, 1992, were \$153.8.

Table F3 FY92 Financial Statement for the Illinois State Geological Survey Lands Unsuitable for Mining Program: July 1, 1991, through September 30, 1992 (\$ in thousands)

Line item	Available appropriation for FY92	Transfers	Available allocation	Vouchered to date	Outstanding obligations this date	Balance available for FY92
Personal Services	\$60.6	0.0	\$60.6	\$60.6	\$0.0	\$0.0
Retirement Contributions	0.0	0.0	0.0	0.0	0.0	0.0
Social Security Contributions	0.5	0.0	0.5	0.5	0.0	0.0
Group Insurance	5.4	1.2	6.6	6.6	0.0	0.0
Contractual Services	0.8	0.0	0.8	0.0	0.0	0.8
Travel	1.9	0.0	1.9	1.8	0.0	0.1
Commodities	0.0	0.0	0.0	0.0	0.0	0.0
Printing	0.0	0.0	0.0	0.0	0.0	0.0
Equipment	0.0	0.0	0.0	0.0	0.0	0.0
Computer-Based Research	1.7	0.0	1.7	1.6	0.0	0.1
Telecommunications	0.9	0.0	0.9	0.9	0.0	0.0
Operation of Automotive Equipment	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS	\$71.8	<u>\$1.2</u>	<u>\$73.0</u>	<u>\$72.0</u>	<u>\$0.0</u>	<u>\$1.0</u>

Table F4 FY92 Financial Statement for the Illinois State Geological Survey Groundwater Protection Act: July 1, 1991, through September 30, 1992 (\$ in thousands)

Line item	Available appropriation for FY92	Transfers	Vouchered to date	Outstanding obligations this date	Balance available for FY92
Lump Sum	\$158.0	\$0.0	\$157.9	\$0.0	\$0.1
TOTALS	<u>\$158.0</u>	<u>\$0.0</u>	<u>\$157.9</u>	<u>\$0.0</u>	<u>\$0.1</u>

Table F5 Financial Statement for the Illinois State Geological Survey Miscellaneous Funds: July 1, 1991, through September 30, 1992 (\$ in thousands)

Line item	Original appropriation for FY92	Emergency budget act	Available appropriation for FY92	Vouchered to date	Outstanding obligations this date	Balance available for FY92
Repair and Maintenance—Building	\$18.0	(\$0.5)	17.5	\$17.5	\$0.0	\$0.0
Repair and Maintenance—Major Equipment	87.0	(2.6)	84.4	84.1	0.0	0.3
Build Illinois Equipment*	5.2	0.0	5.2	5.1	0.0	0.1
TOTALS	<u>\$110.2</u>	<u>(\$3.1)</u>	<u>\$107.1</u>	<u>\$106.7</u>	<u>\$0.0</u>	<u>\$0.4</u>

* Reappropriated for FY92.

